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metal finishing Journal

MAY, 1955



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THIS JOURNAL IS DEVOTED TO THE SCIENCE AND TECHNOLOGY OF PAINT APPLICATION, ELECTRODEPOSITION, VITREOUS ENAMELLING, GALVANIZING, ANODIZING, METAL SPRAYING AND ALL METAL FINISHING PROCESSES.

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IN AND OUT PLATING

THE ART, craft and science of electrodeposition is practised in a variety of ways which range from what can almost be described as backyard methods, which would hardly seem out of place in the workshops of the Cairo bazaars, to the full and effective utilization of modern plant and equipment backed by all the chemical and engineering skills of the age. Between these two extremes there exists a large number of plating plants exhibiting varying degrees of efficiency.

The nature of the electroplating process is such that a perfectly attractive and adequate finish can be produced from the crudest equipment, provided that expensive man-hours are devoted to the preparation and processing of the article. The demands of modern mass production however, require that finishing processes shall be put on the same productive level as presswork and other high-speed production methods. To meet this demand has evolved the modern fully- or semi-automatic plating and polishing line, inserted in a production line and coping with its normal output.

As in many other industries however, the introduction of mass-production methods involves considerable expenditure on capital equipment which may be of such a specialized nature as not to be readily adaptable from one type of product to another (this is particularly true in the case of automatic polishing equipment). Furthermore the high production speeds and split-second timing involved in automatic processing require much more rigorous control if adequate standards of finish are to be maintained.

A manufacturer therefore, having decided on the application of an electroplated finish to a given component, has then to decide whether to install the plant necessary for applying this finish in his own works as part of his own production line, or whether to send the work out for plating under contract. If he should decide to do the work himself he must then decide whether the magnitude of his production, real or projected, is sufficient to justify expenditure on automatic or semi-automatic equipment or whether a simple vat installation will suffice. Such a decision is not an easy one to make, as the costing of internal plating shops for some reason never appears to be entirely satisfactory and the present rate of change and modification of component design can rapidly render parts of an automatic plating installation obsolete or redundant. On the other hand by putting work out under contract, production schedules as well as quality standards can pass beyond the manufacturer's immediate control.

The heart burnings of many manufacturers in this position should be greatly alleviated by the extension of a system which has been recently announced as being set up by a large well-known electroplating company, and of which some details are given elsewhere in this issue. The terms of this scheme are such that the contract plater sets aside a portion of his plant, or indeed, as in the case referred to, installs new plant, which is exclusively devoted to processing his client's products, and to which his client has complete access for inspection purposes.

It would appear that such a scheme whereby the contract plater invests his capital in plating plant with a reasonable guarantee that it will be earning him a fair return on his outlay, and the manufacturer gets his products plated at an economic price and with quality control of his own devising, has much to commend it.

Much criticism is still today being levelled at performance standards of plated finishes and if such a scheme as this could ensure that adequate finishes are applied, without cutting corners to save ha'pennies, it would do much to re-establish electroplate in the position in public esteem which it undoubtedly merits.

Talking Points

by "PLATELAYER"

TOPICAL COMMENT
FROM THE MAIN
LINES AND SIDE
LINES OF METAL
FINISHING

LOOKING AHEAD

NO wild enthusiasm was visible at a recent meeting of the Institute of Metal Finishing when Mr. Alan Smart advocated the use of not less than .002 in. of copper and about .001 in of bright nickel under chromium in order to produce a durable finish on steel for outdoor service. As such a deposit is considerably heavier than that usually specified in current practice, this brings up the question of whether plating specifications, as they exist at present, are adequate. It is no secret that most of them have been drawn up largely on account of their practicability in the trade, having regard to available plant and methods. While Mr. Smart's proposals would lead to a much more corrosion-resisting chromium-plate, it seems doubtful if platers could produce deposits of this kind commercially even if they wanted to. In the meantime motor-car buyers, and manufacturers for that matter, protest vociferously about the quality of the plating they receive, while the accessory suppliers and finishers on whom they so largely depend maintain that all is well—or as well as can be expected.

While chromium-plating has no serious rival, the present state of complacency can safely be expected to continue, aided and abetted by the nickel shortage, which is really irrelevant. The situation may not always be the same however, and the industry would be well advised to do some forward thinking.

TARNISHED REPUTATION

SILVER plate tarnishes, and it is common knowledge that the tarnish develops most quickly when the atmosphere is pervaded by malodorous sulphur derivatives. It was therefore inevitable that sooner or later someone would try to see whether chlorophyll, which has been much publicized as a deodorizer, would inhibit the tarnishing of silver. Work carried out recently under auspices of the D.S.I.R. has shown that this is indeed the case. Acid-free jewellery tissue impregnated with chlorophyll derivatives is now being marketed in this country under license, and the indications are that such paper will be very useful for the wrapping and storage of silver-plated articles.

The problem of protecting silver from tarnishing in service has also been tackled sporadically. A singularly simple and effective method developed some years ago consists in applying a film of

beryllium oxide electrolytically; this film is hard, durable and invisible, but for some reason the process has received only very limited application.

A recent patentee has also conceived the idea of using a polish which contains a salt of a metal capable of alloying with the silver superficially. A typical anti-tarnish polishing compound claimed consists essentially of hydrated aluminium silicate, an ester of a higher fatty alcohol and cobalt or copper sulphate. The extent to which this is likely to be effective is a moot point. There is no doubt, however, that these days a finish which demands regular cleaning inevitably encounters sales resistance, and if a long-lasting process which would reduce the frequency with which silver has to be cleaned could be made available, its popularity would be greatly increased. The method should not, however, detract from the colour of the metal which is its principle charm.

NIGHTLIGHT SAVING

A COLOSSAL amount of money must be wasted up and down the country by lights in factories which someone has not remembered to switch off when they are not required. Fluorescent lighting in particular blends so inconspicuously with natural light, that it is difficult to see that tubes are still on when the sun comes out. In this country, changes in the weather are so frequent that at some times of the year one must constantly be switching lights on and off if the maximum economy in power and in the replacement cost of fluorescent tubes is to be obtained.

In spite of this, it is still very rare to see an illumination monitor in action, even where managements are very free with use of thermostats to reduce wastage of electricity in heating. These monitors are simple photoelectric devices which switch lights on or off when the general illumination level departs from a predetermined standard as the natural daylight varies.

STILL "B.I.F.-ING" :

Walking round the British Industries Fair I was told by several exhibitors that they would not be showing next year. I remember them saying the same last year—and the year before that: yet they still keep coming.

The fair is a form of advertisement, and as such its value is not assessable in terms of hard cash. But they are evidently fearful of the consequences of failure to advertise.

A Paper contributed to
a Symposium on "The
Structure of Electrodeposits"
organized by the Department
of Industrial Metallurgy at
Birmingham University on
March 15, 1955

THE PROPERTIES and ENGINEERING APPLICATIONS of ELECTRODEPOSITS

by R. A. F. HAMMOND B.Sc., A.R.C.S., F.R.I.C.

THE most familiar example of the salvaging of worn or undersized components dates from the 1914-18 war during which a plant was set up behind the lines by a British Army Unit in France to repair worn gun parts by iron deposition. Thus, for the first time, was provided for the engineer what has since been termed a "putting-on tool." Today nickel is normally used in place of iron as possessing superior properties, and the process is more amenable to control. The process of producing thick deposits of nickel for this and similar purposes is known in the trade as "heavy nickel deposition."

Since the introduction of a successful commercial chromium-plating process in about 1925 and the discovery of the very high hardness of electrodeposited chromium this metal has been used for hard-surfacing either as a substitute for case-hardening or sometimes as a supplement to it. This process is referred to by the trade as "hard-chrome plating."

In addition to their use for salvaging and hard-surfacing, thick nickel and chromium deposits are frequently used to provide combined wear and heavy-duty corrosion resistance. Heavy nickel deposits are also used as a means of fabricating by electroforming complex shapes such as cams, press moulds and dies, spray-painting masks, etc., the production of which would be very costly by standard engineering methods. Other electrodeposited metals are widely used for engineering purposes, e.g. thin copper deposits as a stop-off in case-hardening and relatively thick rhodium deposits for electrical contacts and, recently, "hard-anodizing" has been introduced for the treatment of aluminium and its alloys.

In contrast to normal electroplating, most of these applications call for controlled mechanical properties in the electrodeposit and this is parti-

cularly true in the case of the salvaging and hard-surfacing applications which comprise the subject of this paper.

Economics

The repair of a component by heavy nickel deposition involves a fair amount of hand-work and the deposition process may occupy anything from a few hours to a week or two depending upon the thickness of nickel required; moreover, the repaired component frequently has to be finally machined to size. It is clear therefore that the process will normally only be economic on components of substantial replacement cost, but on such parts the saving may be very considerable.

Plating Technique

The plating solutions employed in heavy nickel and hard-chromium plating are essentially the same as are used for decorative plating; so also the equipment and methods of plating are basically the same. Nevertheless since in this type of work exceptionally thick deposits are applied (usually restricted to localized areas) and since particularly high adhesion and controlled mechanical properties in the deposit are required, specialized experience and conscientious attention to detail are needed for success in this field.

In heavy nickel work deposits a quarter of an inch or more in thickness is occasionally applied although 0.10 in. is usually regarded as the maximum economic thickness. Hard-chromium deposits usually range from about 0.0001 to 0.01 in. according to the nature of the component. For comparison the thicknesses of decorative/protective coatings of nickel and chromium are commonly 0.001 and 0.00002 in. respectively.

The greater deposit thicknesses employed in this work are responsible for a number of difficulties. Defects of all types, for example hydrogen

pitting and the growth of nodules, assume a greater importance as the thickness increases. More than anything else, however, to overcome the tendency of electrodeposits to deposit preferentially on "high spots" (e.g. edges and corners) or on those areas nearest to the anode and to be scant on recessed areas, calls for much ingenuity on the part of the plater except on components of simple shape. The "throwing-power" of a plating solution is a measure of its ability to deposit uniformly over the whole surface of the cathode and this varies very considerably for different solutions. The throwing-power of nickel solutions is bad and that of chromium solutions still worse. It is frequently necessary, therefore, for the heavy nickel or hard-chromium plater to adopt various expedients in order to ensure that adequate deposit is obtained in the recessed areas—for example the use of auxiliary cathodes ("robbers") to deflect deposit from the prominent areas or of auxiliary anodes. An extreme case of latter is the deposition in the bore of long narrow tubes.

The insoluble anode process developed in the A.R.D.E. and described by Hothersall and Gardam in a recent paper enables thick and relatively uniform nickel deposits to be obtained in the bore of tubes say 3 or 4 in. dia. and fifteen or twenty feet long. In this process the anode, consisting of a lead or a lead-plated steel rod, is supported centrally in the centre of the tube and is insulated from it. The electrolyte (nickel sulphate, sodium sulphate and boric acid) is continuously circulated through the tube from bottom to top. The effluent solution at the top of the tube is passed to a regenerator in which the periodic addition of a calculated amount of nickel hydroxide powder restores the metal content of the solution and neutralizes the free sulphuric acid liberated at the anode. On leaving the regenerator the solution is filtered and passes back into circuit.

The Adhesion and Mechanical Properties of Electrodeposits

The first requirement of an electrodeposit applied for engineering purposes is that it should be strongly adherent to the basis metal, the second that it should possess mechanical properties (hardness, ductility, tensile-strength, etc.) adequate for the purpose intended, i.e. in the case of salvaging jobs, not inferior to the steel of which the component is made.

Adhesion

In work of this sort "perfect" adhesion should be the aim, i.e. adhesion in which the strength of the interfacial bond and the immediately

adjacent metal on either side is equal to or greater than the tensile strength of either the basis-metal or the deposit (whichever is the weaker); in general, it is possible to attain this standard.

Typical results of quantitative adhesion tests of nickel deposits on a variety of basis-metals are shown in Table I. It will be observed that in most instances fracture occurred within the basis-metal and that, in fact, the "adhesion" recorded is the tensile-strength of this component.

TABLE I
Typical Adhesion Values of Electrodeposited Nickel

Basis-metal	Adhesion (tons per sq. in.)	Location of fracture
Mild steel, rolled bar ...	28	In steel
3 per cent nickel steel, forged	32	" "
Ni/Cr structural steel, hardened and tempered ...	21	" " , near interface
Case-hardened steel ...	22	" " , near interface
Cast-iron (pearlitic) ...	7	near interface
Nickel-coated mild steel ...	28	In nickel
Copper, extruded rod ...	18.5	In copper
Brass "70/30" ...	23.5	In brass
Brass "60/40" ...	19.2	" "
Phosphor-bronze ...	15	In phosphor bronze
Aluminium ...	3.5	In aluminium
Duralumin ...	24	In Duralumin

Work carried out in recent years in A.R.D.E. and published in *Trans. Inst. Metal Finishing* last year showed that the adhesive force between a properly applied chromium deposit and a steel test-piece was consistently greater than the tensile strength of the chromium. From this investigation it is concluded that the true adhesive force of properly applied chromium deposit to a mild steel or low alloy steel base exceeds 25 tons per sq. in.

It now seems clear that, under suitable conditions of preparatory cleaning and deposition, the force which binds the electrodeposit to the basis-metal is atomic in nature, and the crystal structure, i.e. the grain boundaries and orientation of the basis-metal may under favourable conditions be continued in the electrodeposit.

Metallic ions on discharge at the cathode surface produce metal atoms which at the instant of discharge tend to move into vacant spaces in the lattice of the basis-metal. Insofar as this process can continue in an uninterrupted manner the orientation and crystal structure of the basis-metal is continued in the deposit indefinitely and the two components become virtually one member. This can readily be demonstrated when the deposit and basis metals are identical and

capable of being deposited in a coarsely crystalline form (e.g. Cu/Cu, Fe/Fe). It is evident that under such conditions the adhesion will equal the tensile strength of the metal.

Similar effects may be observed with pairs of different metals provided the crystal form and inter-atomic spacing are not too dissimilar. Differences in lattice constant up to approximately 15 per cent can be accommodated and in such cases there will be a region of transition of the structure at the interface from one atomic spacing to the other. In this region which is not likely to exceed 1000Å (approx. 4×10^{-6} in.) the lattice will be strained but beyond it the atoms of the deposit will be spaced normally and the orientation of the basis-metal may be continued in the deposit indefinitely. Owing to the lattice strain in the region of transition it is possible that the strength of the interfacial bond may exceed that of the component metals in such cases.

Again it is readily possible to demonstrate this type of structure metallographically in basis-metals and electrodeposits of coarsely crystalline structure.

Grain-continuation cannot be demonstrated metallographically with fine-grained electrodeposits and these include those mainly used in engineering applications, viz. certain types of nickel and chromium. It can be shown, however by electron diffraction that the orientation of the basis-metal crystals can be copied by the deposit for a small thickness and indirect evidence can be obtained metallographically by a technique originated by Gardam. For example when electrodeposited copper from the acid sulphate bath has been applied to annealed iron over a very thin undercoat of nickel the correspondence of structure between the iron and the copper shows that the orientation of the former has been transmitted through the intermediate nickel layer. Grain continuation between two copper deposits is prevented however by a substantially thicker layer of nickel.

Cleaning Treatments

The attainment of perfect chemical cleanliness and the preservation of this condition on the basis-metal surface up to the instant at which deposition commences will usually ensure high adhesion of the order described. In practice this involves the removal from the work of all surface contamination, e.g. oil or grease, machining lubricants, etc. Gross oxide, rust or scale, are rarely present on components supplied for heavy nickel or hard-chromium plating. Standard methods of vapour degreasing and cathodic or anodic alkali degreasing followed by anodic pas-

sivation in sulphuric acid for steel components or by immersion in "bright dip" for most copper alloys usually suffice to secure the requisite degree of surface cleanliness.

The function of the acid treatment is two-fold: (a) to dissolve surface oxide and (b) to remove work-hardened or "amorphous" metal from the surface which, if permitted to remain, would become embrittled by the hydrogen released during plating thus constituting a weak interfacial layer producing the effect of a poorly adherent deposit.

As a further safeguard against poor adhesion due to hydrogen embrittlement the components are commonly heat-treated at 150 to 200°C for an hour or so after deposition.

Mechanical Properties of Electrodeposits

Nickel is primarily used for the reclamation of worn or the salvaging of overmachined parts—chromium primarily for hard surfacing to increase wear resistance. The mechanical properties of the deposits must clearly not only be adequate to fulfil the function of the steel which they replace, but in the case of nickel deposits—which may have a substantial thickness in relation to the cross-section of the component—the substitution of nickel for steel must not weaken the component appreciably.

Hardness

The indentation hardness of electrodeposited metals is commonly higher and frequently very much higher than that of the corresponding metallurgical product. The cause of the high hardness has been variously attributed to the presence of hydrogen, to small grain-size or to the presence of co-deposited oxide or basic salts. It seems probable that the last two factors are jointly responsible for the high hardness.

The mechanical properties of electrodeposits are also amenable to a very considerable degree of control through the choice of electrolyte and variation in the depositing conditions. Typical hardness ranges for nickel and chromium are 200-400 and 750-950 D.P.H. respectively.

In the case of nickel it has been shown that for a given solution the hardness, grain-size, tensile-strength and ductility are much influenced by the acidity of the bath. Increasing the pH of the solution above a certain critical value causes a sharp increase in hardness accompanied by a reduction in grain-size. The probable explanation lies in the production at the cathode surface of colloidal basic-salts or oxide (resulting from the rise in the cathode-film pH) and the absorption of these compounds on the surface of the

(continued on page 198)

The Use of RADIOACTIVE ISOTOPE TRACER TECHNIQUE in a Study of the Adhesion of ENAMEL COATINGS

by M. LORANT

A CERAMIC or porcelain-enamel coating, to be effective, must adhere to the metal it is designed to protect. Cobalt oxide effectively promotes adherence of porcelain enamel to iron, and for this reason has long been added to enamel ground coats. Despite a great deal of research, however, the mechanisms by which cobalt oxide promotes adherence are not well understood.

Using very sensitive radioisotope tracer technique, the U.S. National Bureau of Standards has recently obtained new information on this important problem. The study, conducted by W. N. Harrison, J. C. Richmond and associates of the Bureau's enamelled metals laboratory, was part of a broad investigation—sponsored by the U.S. National Advisory Committee for Aeronautics—of the mechanisms involved in the adherence of porcelain-enamel and ceramic coatings.

Conventional porcelain-enamel ground coats usually contain at least 8 components. In addition to cobalt oxide, oxides of iron and nickel are usually present. The physical and chemical

TABLE I
Radioactivity count on metal specimens enamelled with radioactive cobalt-bearing enamel, then de-enamelled.

Specimen No.	Firing treatment	Counts per minute After de-enamelling and removal of oxide
1	U	180
2	U	189
3	N	1788
4	N	2345
5	O	2759
6	O	2685

U = Underfired, 4 minutes at 790°C. (1450°F.)

N = Normally fired, 4 minutes at 860°C. (1575°F.)

O = Overfired, 6 minutes at 950°C. (1750°F.)

properties of these oxides are quite similar, and the identification and quantitative estimation of small amounts of one of them in the presence of the others in such a complex system is difficult by ordinary chemical and physical means. For this reason practically none of the data previously reported have been obtained under conditions closely approximating those found in practice. By adding radioactive cobalt as a tracer to the

Using radioactive cobalt as a tracer, the U.S. National Bureau of Standards has recently obtained new information about the mechanisms involved in the adherence of porcelain enamel to steel. This set-up was used to measure the radioactivity—an index of cobalt concentration—of various layers of the enamel-interface-metal system after firing. The sample is inserted in the vertical lead shield, or "lead pig" (left), which contains a Geiger-Muller tube. Radioactivity, as detected by the tube, is counted on the decade scaler (centre).



TABLE II

Radioactivity counts on enamel chips after removal of metal base.
(Counts per minute per square inch.)

Specimen No.	Firing condition	After iron removal			I-KI solution	After oxide removal		
		Inner-face	Outer-face	Diff. (per cent.)		Inner-face	Outer-face	Diff. (per cent.)
1	U	15,755	18,484	14.8	1344	4090	4813	15.2
2	U	16,474	19,659	14.8		3205	3594	10.8
Avg.				14.8				18.0
3	N	14,211	18,246	22.2		2594	3429	24.4
4	N	14,641	18,141	19.3	1664	2484	3193	22.2
Avg.				20.8				23.3
5	O	9,339	14,100	33.8		1917	1926	—
6	O	8,737	13,106	33.3		1818	2581	29.6
Avg.				33.6	2784			29.6

U=Underfired, 4 minutes at 790°C. (1450°F.) N=Normally fired, 4 minutes at 860°C. (1575°F.) O=Overfired, 6 minutes at 950°C. (1750°F.)

frit (glass) used in the coating, the Bureau was able to obtain data on the mechanisms by which cobalt oxide promotes adherence of normally processed coatings of typical composition.

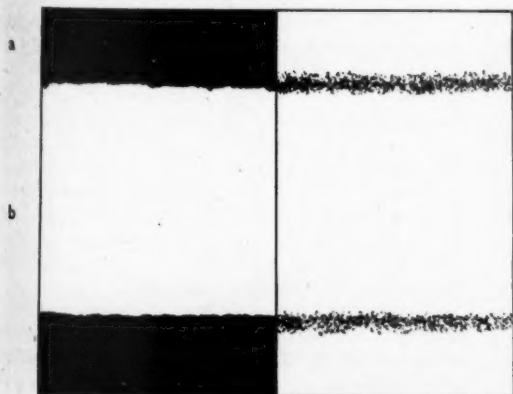
Studying the distribution of radioactivity in coated specimens after firing, it was found that a metallic cobalt layer was formed at the enamel-metal interface, and that near the interface the enamel layer was depleted in cobalt oxide. The amount of cobalt that thus migrated to the interface increased with increased firing, though the total quantity was extremely small—equivalent to a layer of metallic cobalt of the order of 0.01 micron (about 0.4 millionths of an inch) thick for normal firing. The cobalt deposit apparently did not penetrate into the enamelling-iron base during normal firing.

In the investigation, small specimens of 18-gauge enamelling iron were coated with a porcelain-enamel to which radioactive cobalt oxide had been added. After either underfiring (4 minutes at 790°C. (1450°F.)), normal firing (4 minutes at 860°C. (1575°F.)), or overfiring (6

minutes at 950°C. (1750°F.)), the specimens were de-enamelled with molten sodium hydroxide. Under the conditions of the experiment the sodium hydroxide readily dissolves the enamel and partially dissolves the iron oxides present at the interface, but the metallic iron and cobalt are not affected. After measurement of radioactivity of the specimens with a Geiger-Müller counter, the iron-oxide layer was removed by agitation in ammonium citrate solution (which does not affect metallic cobalt), and the radioactivity was again counted. These measurements indicate the amount of cobalt present at the interface in metallic form (see Table I).

To study the cobalt distribution in the enamel layer itself, the specimens were ground through from one side until almost all of the iron was removed. Treatment with a solution of iodine in potassium iodide removed the rest of the iron and also the metallic cobalt layer, leaving only a thin shell consisting of the iron oxide and enamel layers. The radioactivity of the resulting

(continued in page 198)



The left-hand portion of this figure is a photomicrograph ($\times 50$, unetched) of a section of an enamelling-iron sheet (b) after de-enamelling and mounting in plastic (a). The specimen was coated with enamel containing radioactive cobalt and overfired. The enamel was then removed with molten caustic soda and the specimen mounted. The cobalt concentrated at the enamel-metal interface but did not penetrate the surface of the metal.

The right-hand portion is an autoradiograph (enlarged $\times 50$) of the specimen made by letting radiation from the specimen impinge directly on to the photographic film. The lines at c show the distribution of the cobalt. Because of scattering of radiation striking the photographic film, resolution is inherently poor—the actual cobalt layer is very much thinner than the width of the photographic line indicates.

The Use of Radio Isotopes in the Study of Enamel Adhesion

(continued from page 197)

solution was checked for an indication of the amount of metallic cobalt at the interface, and radioactivity counts were made on each side of the chips of enamel. The iron oxide at the enamel-metal interface was then removed by solution in ammonium citrate, after which radioactivity counts were made of the ammonium citrate solution and again of the chips. These various measurements give a picture of the distribution of radioactive cobalt in the enamel layer (see Table II).

To obtain a picture of the cobalt distribution near the interface by a different technique, a normally fired specimen was mounted in plastic and ground at a slight angle to give a large-scale section through the interface and into the metal. An autoradiograph of the section was then made by letting radiation from the specimen impinge directly on a photographic film that was in contact with the specimen. Like the other observations, the autoradiograph shows that the radioactive cobalt concentrated at the interface but did not penetrate the metal.

In another test of the degree of penetration, a normally fired specimen was de-enamelled with molten sodium hydroxide. After a count of its radioactivity, the specimen was then treated with ammonium-citrate solution to remove the tightly adherent film of iron oxide, rubbed with a damp rag to remove any loose particles of cobalt metal, and again tested for radioactivity. The count was found to have been reduced 85 per cent by this citrate-and-rubbing treatment of the surface, indicating further that there was very little penetration into the metal.

Substantial penetration of the iron base by the radioactive cobalt was observed, however, in a coated specimen that was heated in air at 700°C. (1300°F.) for 270 hours after normal firing. When such a specimen, after de-enamelling, was treated with the ammonium-citrate solution and rubbed with a damp cloth, the radioactivity count was reduced by only 10 per cent. An autoradiograph likewise showed considerable radioactivity below the surface of the iron.

The cobalt deposit is believed to be metallic because it is removed with the iron base metal during the iodine-potassium iodide treatment, but is not completely removed by 65 hours of treatment with ammonium citrate. The experiments performed so far do not indicate whether the cobalt deposit consists of the pure metal or of an alloy with iron, nickel, or both. This may be clarified in future phases of the investigation.

Properties of Electrodeposits

(continued from page 195)

growing crystallites inhibiting grain-growth and promoting fresh nucleation.

Tensile Properties

The tensile strength and ductility of electrodeposited nickel vary with the hardness and broadly correspond to those of steel. The Young's Modulus (23 to 30×10^{-6}) is also similar to steel. (Brenner and Jennings.)

The tensile strength, and modulus of elasticity of various types of electrodeposited chromium have been measured by Brenner. His results were erratic and he found that the values obtained were lower than the true physical constants and were determined by the relative unsoundness of the test-pieces. He reports, however, that the tensile strength varies from about 15,000 lb. per sq. in. to 80,000 lb. per sq. in.

TABLE II
Typical Tensile Properties of Electrodeposits

Deposit	Ultimate Tensile Strength	Elongation (per cent)
Nickel (soft)	28 tons per sq. in.	35
Nickel (hard)	55	6
Copper	20 to 25 tons per sq. in.	40-55
Chromium	15,000 lb. per sq. in. to 80,000 lb. per sq. in.	< 0.1
Iron	75,000 lb. per sq. in. (60,000 yield pt.)	—

the lower value being typical of the deposit normally used for hard-chromium plating. Electrodeposited chromium is brittle and Brenner calculates that the elongation at fracture must be less than one-tenth of one per cent.

The tensile properties of various electrodeposits are summarized in Table II.

(To be concluded)

NEW PRESIDENT OF A.D.A.

At the Annual General Meeting of the Aluminium Development Association, held in London on the 22nd April, Dr. Horace W. Clarke (Chairman and Managing Director of James Booth & Co. Ltd.) was elected president.

Dr. Clarke was one of the founders of the Development Organization which was created in 1941, and when it was absorbed by the present Association ten years ago, he became its first President. He has again been elected to hold this office in the centenary year in Britain of aluminium as a commercial metal.

At the same time the Hon. Geoffrey Cunliffe, Deputy Chairman and Managing Director of the British Aluminium Company Ltd., was elected vice-president.

This description of a method of barrel finishing developed by Husqvarna Vapenfabriks AB, Sweden is based on a Paper submitted by the author to the 5th International Mechanical Engineering Congress.

BARREL FINISHING of Metal Components by the 'ADVANCED' Barrel Process

by Sixten ARENSTEN

THE use of horizontally rotating barrels or boxes for cleaning or scrubbing of parts, cast or forged, has been in operation for a long time. The parts are tightly packed in barrels, sometimes together with slag, scrap or specially made slugs or stars. The rate of rotation is high, 100 r.p.m. or more, and the parts thus knock or grind against each other. The object is to remove sand, soot or mill scale or, in other words, to clean the parts, to fettle them and at the same time break away or knock off sharp edges, flash or burrs. Hence the process is called tumbling. It is often carried out in the dry state and is completely uncontrollable. It is simply a question of the parts knocking and scraping against each other and the whole operation is allowed to run as best it may.

This very primitive procedure must be clearly distinguished from the "Advanced" barrel process the two processes having only certain pieces of equipment in common.

The "Advanced" process differs from the old tumbling process in that it is nearly always a wet method. The main principle is that during processing the parts never touch each other but are the whole time well embedded in a medium of a specially prepared type. This medium contains the grinding or burnishing materials, exactly chosen with regard to shape, size and physical surface properties.

For every job there is a definite amount of water to which are added chemical agents each serving a different purpose. These agents are chosen according to the material of the parts to be treated and the surface finish required. The speed of rotation of the barrel is very much less and so chosen that due to the friction against the barrel walls the whole load is raised to a definite angle of repose. On further rotation a certain depth of the upper or sliding layer is continually rolling and tumbling back to the bottom of the barrel. The parts are embedded in the medium all the time and thus they are subjected to the friction or grinding action and to the pressure created by the load.

In order to obtain a specified edge radius or a more or less smooth and burnished surface on work-pieces that have been turned, punched, drawn, forged or pressed, it is generally necessary to carry out very extensive and costly manual operations, even if using grinding or burnishing wheels. This is especially necessary for parts subsequently sent to be electroplated or enamelled, since they must pass through a large variety of operations such as deburring, rounding-off corners and edges, grinding to obtain a given smoothness and evenness, glazing and superfinishing; all of which necessitate highly qualified and trained operators. The rapidly increasing labour costs have, therefore, in a marked degree, made it necessary to replace this time-consuming and costly manual work with a simple and cheap process for mass production.

The "Advanced" barrel process is such a process, not only because in its most advanced form it can solve certain production problems in a highly satisfactory way, both technically and economically, but also from a strictly economical point of view. It is not uncommon to save from 80 to 90 per cent of the direct labour costs when using this process to obtain a stipulated surface finish as compared to the conventional grinding-wheel method. The process is not dependent on trained and skilful operators. Rejects and differences between the parts themselves occasioned by individual treatment of each part are obviated. Change-over from one job to another is simple. No expensive equipment is required, maintenance costs are low and the cost of expendable materials is small compared to the wheel or band methods. It is not necessary to alter existing equipment because of a change-over to other production parts. The method is easily adaptable and can be installed in part or complete anywhere in the production line. The only requisites are access to water mains and drainage pipes. Expensive exhaust and hence accompanying air inlet systems, as for the wheel or band method, are unnecessary. Accident risks are small. The process is completely controllable, hence it is possible to set up definite work specifications.

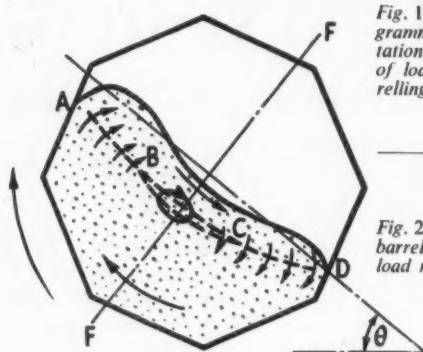
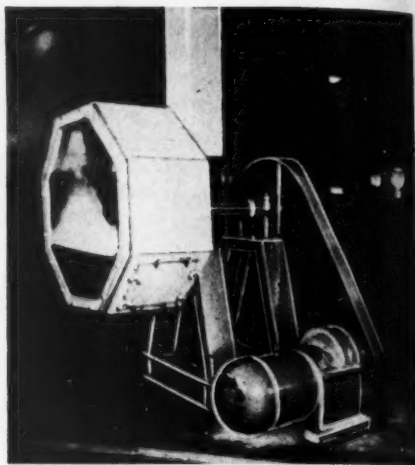


Fig. 1 (left). — Diagrammatic representation of movement of load during barreling.

Fig. 2 (right). — Test barrel for studying load movements.



Stipulated surface finishes may be specified and are reproducible. It is also possible to grind-down to stipulated dimensions, to obtain a perfect identity of parts conforming to specified quality requirements, and to set timed operations.

The process may be designated a rolling process, as compared to the violent motion in the tumbling process, and can be divided into three chief specialized types:

- (1) Deburring and edge rounding, with the main purpose of removing burrs from cutting operations as well as removing minor flash on castings.
- (2) Grinding, with the main purpose of removing stock from the surface with no particular intent to deburr. Since the grinding effect is much less on plane surfaces than on corners and edges, and since the unit pressure there is greater, jobs 1 and 2 may be combined.
- (3) Burnishing, with the main purpose of imparting a high finish and lustre to the surface *without* removing any stock.

Those wheel or band jobs capable of being performed with barrel processing are:

- (a) deburring
- (b) grinding
- (c) glazing
- (d) polishing and buffing

Fig. 1 shows schematically how the load moves during rotation of the drum and Fig. 2 shows the test barrel in which the mechanism of tumbling may be studied. Since the medium used has an abrasive function some at least of the forces brought into play during the rotation of the barrel must be frictional forces. Solely pressure forces would simply result in the surfaces of the parts being scratched or indented or lead to the abrasive material being embedded in the surfaces. That pressure must be exerted, however, is apparent from the fact that the load has weight. The frictional forces result from the various movements of the load in the barrel.

When the barrel turns, a rotating movement up the side of the barrel is imparted to the load and medium until the forces of gravity exceed those of friction between the load and the barrel sides as well as those within the load itself. Thus, the upper layer rolls down to lower levels in the barrel. When employing an octagonal barrel with a diameter of 750 mm. and a speed of 20 r.p.m. this so-called sliding layer is approximately 60 to 70 mm. thick. At least 90 per cent of the barrel processing is performed in this zone. Very little processing is observable as the parts move up from the barrel bottom.

It follows that the length of slide, *i.e.* the line of the roll, should be as long as possible and this is done by choosing the optimum values for barrel size, speed and degree of filling. It has been shown that the total weight of the load has only a minor effect on either grinding or burnishing.

The line of roll is longest when it coincides with the barrel diameter, *i.e.* when the barrel is half-filled. If the barrel is more than half-filled, the line of roll is less. If less than half-filled, it is possible that the thickness of the sliding layer decreases and the movement of the load becomes so small that hardly any grinding or burnishing takes place. Too small a load, and also too low a speed of rotation tends to leave the load on the bottom of the barrel where it only rocks to and fro. It is impossible to decide exactly where the optimum conditions for the process lie. It depends on the diameter and length of the barrel, speed, size of load, size, weight and shape of the processed parts, choice of medium and much else besides.

There exists a sharp limit to what can be done in a small-diameter barrel compared to a larger one. A 400-mm. dia. barrel cannot be forced to

give as large an output as an 800-mm. one, even if the former turns at a greater speed. The extra processing carried out in the latter half of the longer sliding zone cannot be made good by increasing the speed of the smaller barrel. The factors affecting the time required for tumbling may also be discussed in an analogous manner. Each individual case has its own optimum conditions and its own limits. Hence, complete data for all processed parts should be noted on special operation cards. Always using this data as a basis for subsequent processing, better results, a higher finish and shorter tumbling times may be arrived at. There are no standard data available that are applicable to all cases. Hence the given data are of a more general nature.

Size and Shape of Barrel and Lining

It is necessary to have a variety of barrel sizes, depending on the number, size and weight of the parts. Customary sizes are 450 mm. and 750 mm. dia., and length approx. 700 mm. and 1,000 mm. respectively. The load for the larger barrel is about 500 kg. when the grinding medium consists of stone or alundum, and about 900 kg. when steel shot is used. A practical optimum ratio between the diameter and length of the barrel must take account of these masses lest the processed parts be deformed or crushed. There must also be a reasonable relationship between the dimensions of the barrel and those of the parts. Long objects like pokers cannot be processed in a barrel having such a large diameter that they are able to wedge and interlock across the barrel. Some parts, having to be attached to racks inside the barrel, also demand more room. The larger-sized barrels may sometimes be divided into sections so that assorted parts or small batches can be processed in the barrel simultaneously.

The most efficient type of barrel is the octagonal, horizontal, closed barrel made of steel and capable of rotating at varying speeds and sometimes also in reverse. This is particularly advantageous when processing parts attached to fixtures whereby all sides may be treated in the same mounting.

The barrels are made of 6 mm. welded sheet steel and lined internally with 45-mm. wooden boards, usually knotted pine wood. The purpose of the lining is partly to protect the objects when striking the sides of the barrel and partly to protect the barrel itself from wear. The wooden lining is standardized and series manufactured. It is stored in complete sets for each barrel and is easy to replace.

Some barrels are lined with hard rubber. This lining is 4 to 5 times as durable as wood but generally it is not economical. A wooden lining lasts from 3 to 6 months, is cheap, and easily replaceable. Renewal or repair of a rubber lining

is rather expensive as the whole barrel must be dismantled and sent away. Under certain circumstances a rubber lining may be justified, for instance if there is not a sufficient number of barrels available and it is necessary to use the same barrels for different materials. It is bad practice to use the same wooden-lined barrels for aluminium and stainless steel as in the former case the load must be basic and in the latter case acidic. Wood cannot be washed so clean that it will not indirectly react chemically. With rubber lined barrels this disadvantage does not exist and hence these barrels are superior for burnish processing.

Rotation Speed

This factor has already been referred to in connexion with the length of slide. It is possible to obtain an increased rate of processing by increasing the speed, but only within very narrow limits. With a load increase of 10 per cent, i.e. increased from 50 to 60 per cent it is in some cases possible to obtain the same rate of processing on this larger load by increasing the speed (had the speed remained the same a 60 per cent load would have given a lower rate of processing since the length of slide is shorter) but in actual production with its multitude of part types, it is impracticable to have barrels built for such limited variable speeds; this equipment belongs to the development department. The most usual speeds are 10, 15 and 20 r.p.m. but even 5 and 30 r.p.m. are sometimes needed. A circumferential speed of 30 to 60 metres per minute should be suitable for a great variety of parts, provided that the barrel diameter is not less than 450 mm. Large and heavy objects, as well as those of soft metal or parts mechanically weak require low speeds. A high degree of finish is likewise attained by using low speeds.

The Load

By load is understood all the objects and parts to be processed along with abrasives and burnishing material of various kinds—the media. The total load hence consists of the parts and the media, along with water and divers chemical agents or ready-made compounds.

The volume of the load has already been mentioned in the discussion on the greatest length of slide. This length is a maximum for a 50 per cent barrel fill. For a 75 per cent fill the finish is better but a longer time is required.

The size, shape and weight of the parts determine the amount of medium to be used to keep them apart during processing, and the form of the parts and the holes in them determine in turn the size of the particles of abrasive medium to be used. Since it is the latter that does the grinding or burnishing, it must surround the parts on all sides. In addition the abrasives also have to keep

the objects apart. The parts must always be well embedded in the medium and hence it must be observed that the amount of medium is proportionately greater than that of the parts. Account must also be taken of the holes in the parts and of the air spaces round the abrasive particles. Experience and experimenting will decide which size of barrel to use for a given load of a fixed number of parts of a given type and how much medium to add.

Too little medium results in massive objects falling too heavily hence causing surface defects. In addition the abrasive is quickly crushed down and the barrel lining rapidly worn out. In general it is possible to reckon for most materials with a bulk ratio for medium to parts of 1:2 to 1:10. In special cases, dependent on the shape or massiveness of the parts, a ratio up to 1:25 may be necessary. For not so fragile or hard parts 1:2 to 1:4 may suffice while for soft materials 1:4 to 1:8 is satisfactory.

Media

The term "medium" is applied to those solid bodies that, together with the parts, are put into the barrel in order to subject the parts to a superficial abrasive or burnishing action. At the same time the medium keeps the parts from coming into contact lest they be damaged during the actual processing.

The various types of media may be classed into 4 groups:

- (1) *Natural stone*: generally macadam stone, grit and sea sand;
- (2) *Synthetic stone*: mainly aluminium oxide (alundum);
- (3) *Organic media*: wood, pieces of leather etc.;
- (4) *Metallic materials*: cuttings of zinc wire etc. or hardened steel shot, disks, slugs and so on.

Although there is an innumerable number of tumbling media in use, there is, however, none that is most economic or suitable for all types of tumbling processes. The natural medium for instance has the disadvantage that it is uneven and its superficial state alters. This the synthetic stone does not do, but on the other hand it is more expensive. There is a widespread misunderstanding that a hard material grinds faster than a soft one. However, it is not the hardness of the medium that is wholly operative but its superficial condition. For instance a soft material with a rough surface grinds faster than polished steel shot. Hence it is often necessary to choose one type of medium for the first part of the process, as for example, for deburring and rough grinding, and then another medium to give a smoother and finer finish or a glossy surface.

It may sometimes be of advantage to split up the tumbling process to incorporate a mechanical

operation, e.g. a milling operation. It may also happen that a slot is milled in a part, the edges of which slot must not be rounded, whereas other edges must be well rounded. To achieve this the part is processed with a medium having so small a particle size that the slot is packed tight with the medium. Afterwards a coarser and more suitable medium replaces the initial one and the processing is completed. Hardened parts requiring a burnished surface, may prior to hardening be rough and fine processed and after hardening, burnished.

The impression that the specific gravity of the medium should be of the same order of magnitude as the parts lest separation occur, is in some measure inaccurate. This is true only at speeds greater than those used here. There is sufficient friction in the barrel to prevent a separation, even when there is a great difference in weight between the parts and the medium. A light material such as aluminium may be processed with a heavy medium such as steel shot without the aluminium parts "floating" up. The rule is, however, that should there be a very large difference between the specific weights, the speed of rotation must be low.

The size of the individual pieces comprising the medium must be chosen so as to conform to the shape of the parts in order to make contact everywhere. Likewise it is necessary to take holes and slots in the parts into account. Sometimes it may be advantageous to mix different particle sizes. A large particle works faster than a small one and removes stock faster on sharp edges and corners. This is due to the fact that its area of contact with the part is relatively smaller and the total weight greater compared with a smaller particle. Hence the abrasive effect is concentrated on a smaller area. For this reason the largest size of medium commensurate with the processed part is used for deburring etc. The same conditions hold generally for burnishing media, i.e. steel shot, etc. Here also small shot gives a high lustre but large shot burnishes at a greater rate.

It has been mentioned earlier that the surface condition of the medium influences the tumbling result. The surfaces must be kept as clean as possible; hence it is necessary to wash the medium and to rinse out the accumulated sludge and dirt. Brass, aluminium and zinc, etc. are often discoloured by the fines from the medium being embedded in the metal surface. It will often be imperative to rinse out the sludge and wash the medium during the actual processing. Washing is carried out directly in the barrel, the lid of which is fitted with a grid. A development of this idea is to allow the whole barrel, which is then perforated, to rotate in an open tank containing water with additions, the so-called *submerged*

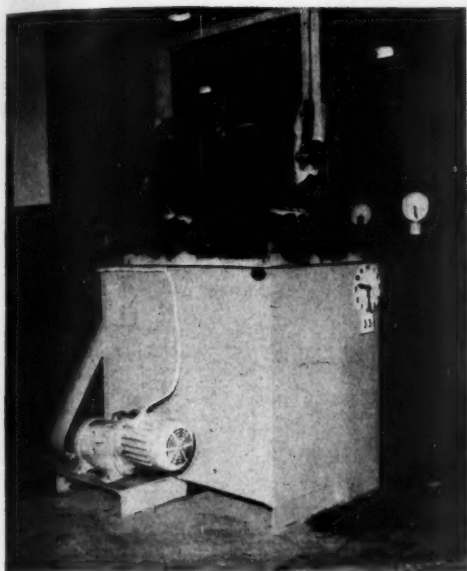


Fig. 3.—Perforated barrel for submerged tumbling.

tumbling, Fig. 3. All sludge from the barrel leaves it and settles at the bottom of the tank. The method is particularly suitable for large or soft parts since the cushioning effect of the water is greater in this instance. Also for small parts demanding special care as regards colour, finish and lustre the method is extremely suitable.

If cleanliness is a pervading stipulation for the tumbling process, it is all the more applicable to the medium used for burnishing, *i.e.* for steel shot, etc. which must be kept scrupulously free from rust and corrosion, be absolutely smooth and shining. If this medium has to be stored only for a few days before re-use, storage may be effected in the barrel. The medium should be well covered with water to which a little caustic soda has been added.

Water and Compounds

The chief purpose of the water is to act as a cushion between the parts, the medium and the sides of the barrel. The amount of water controls the grinding rate. Reducing the volume of water increases the grinding rate and the processing time is shorter but a coarser surface results. Increasing the water gives the opposite results. The water level may vary within rather wide limits, from 100 mm. below to 250 mm. over the top surface of the load. The usual height for deburring and grinding is level with or slightly below the surface of the load. It is just as important to keep the parts free from oil, grease, dirt or rust, etc. as it is to keep the medium clean. Often the simplest

way to clean the parts is by the usual degreasing or pickling operations.

To the water an added various chemical agents (detergents, dispersing agents and the like) having cleaning and rust-protective properties and also lathering agents and lubricants. All these compounds are obtainable ready for use, as powders, easy to add and made up for various uses and metals. The compounds should be so composed that the *pH* of the solution does not alter during processing, thus protecting the metal parts from attack and the operator from injuries during handling. The metal surfaces should be clean and free from skin and oxides and any coating formed should be easily removable. With ferrous parts there should be some degree of rust-prevention. As regards the latter, and specially when deburring or coarse grinding with water only and abrasive medium, caustic soda or trisodium phosphate is added (approx. 6 gm. per litre). The water is hereby made softer and corrosion on drying is prevented. Parts and medium are also kept clean.

Perhaps the most important function of the chemical agents is to control the *pH* of the solution, which in turn determines the lustre and colour of the processed parts. Tests have shown that to obtain the best "colour" on processed parts the processing solution should have approximately the *pH* values shown in Table I.

TABLE I

Material	<i>pH</i>	Reaction
Ferrous	12	Basic
Zinc and aluminium	8	
Brass, bronze, copper	4	Acidic
Stainless steel	3	
Removal of scale	1	

If a basic reaction in the barrel is required, *i.e.* a *pH* between 6 and 14, a sufficient quantity of trisodium phosphate and calcined soda in equal proportions is added. As a guide 20 litres of water require about a dessertspoon full of the mixed reagents for a *pH* of about 12. For an acidic reaction, *i.e.* a *pH* between 1 and 5, hydrochloric or sulphuric acid is added. A *pH* of 1 requires about 4 cc. of sulphuric acid per litre of water. Generally some hydrogen sulphide is hereby produced, but this may be removed by an addition of hydrogen peroxide (H_2O_2).

The above quantities are only to be regarded as a guide. Each individual case must be tried out by itself by varying the *pH* value to obtain the best result. The *pH* is best determined by special indicator paper. An unsuitable *pH* may result in discoloured parts, the surface may be attacked, stained or roughened. Previously it has been

stressed that the same wooden-lined barrel must be used for the one metal only. A faulty pH may give rise to serious trouble, as for instance if light-alloy parts are processed in an acidic solution, hydrogen gas is evolved briskly and the barrel may be ruptured by an explosion.

Case-hardened steel parts processed in an acidic solution obtain a lightly etched surface and must be reprocessed. After a few such treatments the hard case disappears.

Tumbling Time

There are of course no general norms or rules for the time of tumbling and this must be arrived at experimentally for each individual case. As a general indication of the order of magnitude, the following times may serve as a guide:

Deburring	15 minutes to	15 hours
Grinding	1 hour to	100 "
Polishing	15 minutes to	15 "
Burnishing	15 minutes to	3 "

Pretreatment of Parts

Like the media, it may sometimes be necessary to pretreat the parts in order to make them fit smoothly into the processing sequence. Very dirty and oily parts should be degreased prior to tumbling, as grease reduces the grinding efficiency. Furthermore, oil and grease have an unfavourable effect on the process by making the walls of the

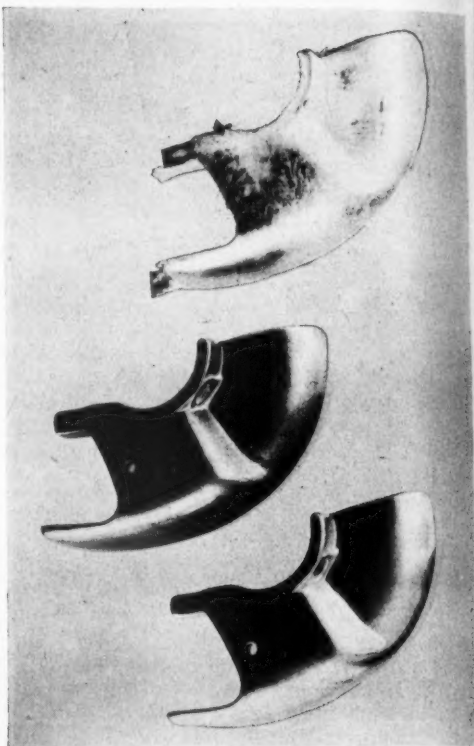


Fig. 4—(above). Progressive stages in finishing of zinc die casting, bright dipped after roughing and before burnishing.

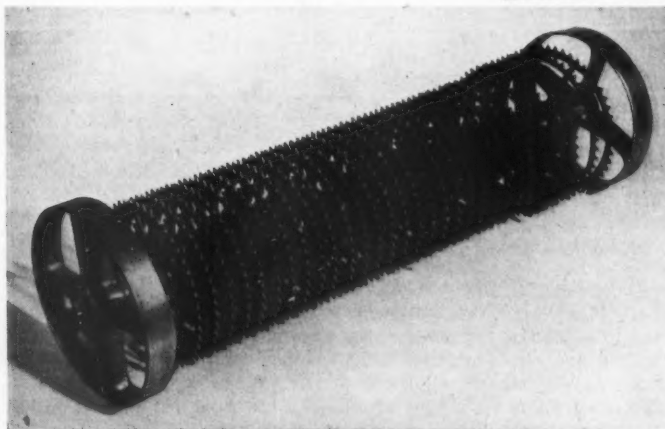


Fig. 5—(left). A rack of bicycle chain drive wheels jugged for deburring of teeth.

barrel greasy as well as the abrasives. Exceptionally large burrs and flash should be removed by hand grinding, as well as heavy draw markings and laps, etc. It often happens with plane surfaces that the "deep" polish effect sometimes required cannot be

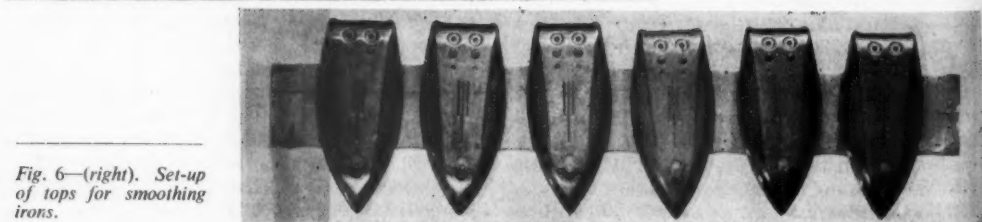


Fig. 6—(right). Set-up of tops for smoothing irons.

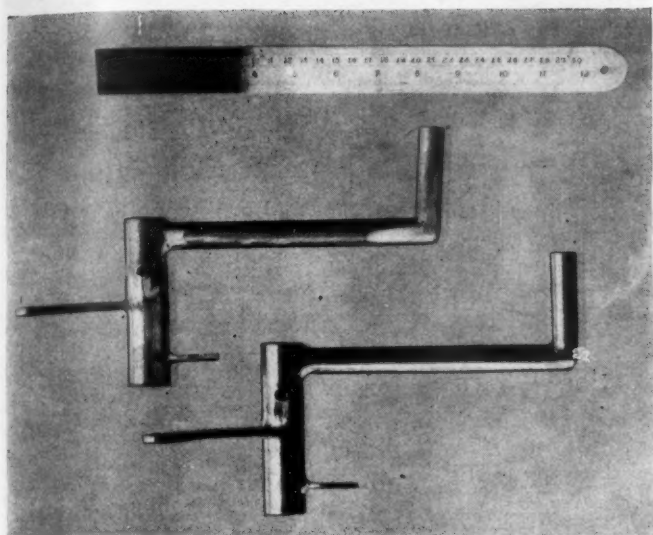


Fig. 7 — (above). Motor-cycle foot-pedal brake lever.

obtained. Instead this finish must be produced manually.

Separation of the parts from the medium is often done by magnet. This results in some of the parts becoming magnetic. Those parts that are to be electroplated subsequent to the tumbling process should be demagnetized prior to plating as otherwise the plating will be rough and coarse. As a result of the tumbling the surface is subjected to a shot peening effect which makes it hard and compact. Parts of sintered steel have their superficial hardness increased by 10 to 12 per cent which makes them considerably more rustproof.

Bright Dip

The colour of a metal surface cannot be improved by ball burnishing. Should the surface be stained or oxidized, no part of it is removed by ball burnishing (the surface irregularities are only smoothed out). Only a peening effect results and no honing, or at least only a negligible amount. Hence it is important that such corroded areas are removed and that the surfaces are spotlessly clean and show the true colour of the metal prior to burnishing. This may be accomplished by chemical etching methods, *i.e.* the bright dip. The acids used are different for different classes of work, such as nitric acid and chromic acid, and are rather objectionable to handle. They must be treated with special precaution and are resorted to only in cases of extreme necessity. Fig. 4 shows a pressure-die-cast zinc part that was dipped for half a minute into a mixture of chromic and sulphuric acids in between the grinding and burnishing operations. The bright dip results in a

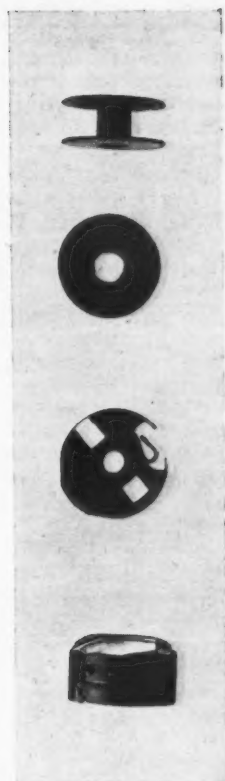


Fig. 8 — (right). Sewing machine bobbin and bobbin holder.

smoothing out of the surface, *i.e.* the remains of relatively large-sized irregularities are eroded to form microscopic "hills and dales" which are finally levelled off during burnishing.

Some Examples of use of the Process

Exceptionally heavy parts or those of complicated shape, such as gear wheels or the like, must be secured in the barrel, lest they damage each other during processing. The medium moves round the parts and the barrel must be reversible so that the medium can make contact with all areas of the parts.

Fig. 5 shows how chain drive wheels for bicycles are clamped for deburring the teeth. The tumbling time was 22 hours with abrasive gravel of 16 to 22 mm., and the water level ± 0 mm. Subsequent tumbling was in sawdust. Besides markedly improving the quality a 50 per cent saving in labour costs resulted.

Fig. 6 shows another set-up of tops for smoothing irons. Draw markings were removed by hand grinding. A tumbling time of 24 hours was necessary with 6-mm. steel discs, with a water level of ± 0 mm., using flour abrasive, 12.5 gm.

Fig. 9.—A view across one of the barrelling departments at Husqvarna.

per litre of water and 7.5 gm. of caustic soda per litre. Subsequent tumbling was in deciduous wood sawdust for 3 hours; labour saved approx. 60 per cent.

Fig. 7 shows a motor-cycle foot-pedal brake lever; the welds were hand rough ground. The tumbling time in gravel of 16 to 23 mm., was 24 hours. The water level was ± 0 mm. with 10 gm. caustic soda per litre. Shot burnishing was for 1.5 hours, with 5 gm. of compound per litre for steel. Tumbling in deciduous wood sawdust was for 0.5 hours and labour saved approx. 90 per cent.

Fig. 8 illustrates a case of processing to a definite size. The parts are a bobbin holder and bobbin for a sewing machine. The bobbin was turned to definite dimensions to fit the holder with a given allowance. The bobbin whose diameter is 21.19 mm. must have well-rounded edges. This rounding was done by fresh gravel of 16 to 23 mm., the time of tumbling being 2 hours and the water level ± 0 . The reduction in diameter was then 0.02 mm., i.e. to 21.17 mm. The parts were dried in sawdust and subsequently hardened and tumbled for 6 hours with alundum No. 8 ($=2.5$ to 3 mm.). The water level was $+30$ mm.



and the compound for hardened steel parts was 3 gm per litre. Approx. 90 per cent saving in labour costs was obtained, compared to older method.

Only iron, steel and the commoner metals for industrial use have been considered in this paper. However, the process is widely used for other materials, including plastic parts. Principally, the treatment is the same, the operations being called ashing, polishing, waxing and lustering. It is mainly a question of various media and compounds.

BRITISH NON-FERROUS METALS RESEARCH ASSOCIATION

Minister of Supply is Chief Guest at Annual Luncheon

THE annual luncheon of the British Non-Ferrous Metals Research Association was held at the Savoy Hotel, London, on May 2, and was attended by over three hundred members and guests. Dr. Maurice Cook, Chairman of the Council of the Association, presided at the function and the principal guest was the Minister of Supply, Mr. R. Maudling.

Proposing the toast of the Association, the Minister referred to the fact that the subscription income from industry to the B.N.F.M.R.A. was at the moment slightly less than the maximum amount qualifying for the D.S.I.R. grant and he pointed out the obvious advantages to be gained by taking up the Government grant to the full.

In replying to the toast, Dr. Cook stressed the point made by Mr. Maudling and observed that the D.S.I.R. grant was subject to continual review and

tended to become increasingly difficult to achieve.

The toast of the guests was proposed by Mr. F. C. Braby in the regretted absence through illness of Mr. W. F. Brazener. The guest list included a number of eminent representatives of Government Departments, among whom were Sir Hugh Beaver (Chairman, Advisory Council, D.S.I.R.), Sir John Lang, G.C.B. (Secretary, Board of Admiralty), Mr. F. J. Erroll (Parliamentary Secretary, Ministry of Supply), Sir Edward Boyle, Bt. (Parliamentary Secretary, H.M. Treasury), Sir James Helmore, K.C.B., K.C.M.G. (Permanent Secretary, Ministry of Supply), Sir Ben Lockspeiser, K.C.B., F.R.S. (Secretary, D.S.I.R.), Sir Owen Wansbrough-Jones, K.B.E., C.B. (Chief Scientist, Ministry of Supply).

On behalf of the Guests Mr. A. B. Waring responded to the toast.

METAL FINISHING RESEARCH
A Survey of its Organization,
Existing Facilities and
Current Work

Tin Research and the Metal Finishing Industry

by Ernest S. HEDGES, Ph.D., D.Sc., A.R.I.C., F.I.M.*

IN forming a picture of the industrial uses of tin throughout the world a feature which stands out prominently is that nearly half the world's tin is used as a coating on other metals.¹ It is natural, therefore, that in planning the laboratories and the research programmes of the Tin Research Institute, the needs of the metal-finishing industry should have ranked very highly. Indeed, a considerable fraction of the Institute's scientific staff is concentrated in four departments which have a direct bearing on metal finishing, namely the departments of Electrochemical Research, Electroplating Development, Tinfoil, and Corrosion.

As the work of the Tin Research Institute in this field extends over more than twenty years, it is only possible in this article to select a few topics for discussion, but it may also be of interest to record some of the guiding principles behind the selected research projects.

Electrodeposition of Tin Alloys

The electrodeposition of alloys containing tin is a field which the Institute has made peculiarly its own in the sense that there has grown up a school of electroplating having a definite character. Initiated by D. J. Macnaughtan, the school has been particularly associated with the names of R. M. Angles, S. W. Baier, J. W. Cuthbertson and A. E. Davies and many others have passed through it. For more than fifteen years it has been under the direction of the present writer.

The literature of electrochemistry is not lacking in references to the electrodeposition of binary and, occasionally, ternary alloys; but on examination it will be found that most of the work described has been conducted during the last twenty years. Nevertheless, the idea of alloy plating was not entirely new even at the beginning of this century, for instructions for plating copper-tin bronze alloys are given in some of the older practical manuals dating from the nineteenth century. Nowadays, scores of pairs of metals have been co-deposited in the laboratory, but even so, only a few processes have proved

successful on an industrial scale and commercially acceptable.

As usually laid down, the theory of alloy deposition is very simple at first sight; it is simply a question of so arranging the conditions of electrolysis that the deposition potentials of the metals which it is desired to co-deposit are close together. However, it is not at all easy in practice to apply this simple principle, because there are so many variables in plating conditions which influence the deposition potential of each metal, not always operating even in the same direction. Among these are the composition and concentration of the electrolyte, the cathode current density, the temperature, pH, degree of agitation, and the presence of "addition agents." Added to this, in some cases it is clear that one of the metals has an influence on the deposition potential of the other, to such an extent that it is even possible to electrodeposit alloys of metals which cannot be electrodeposited singly.

On the whole, therefore, it is impossible in the practical sense to forecast the conditions under which the deposition potentials of two metals can be made equal. Even the "single electrode potentials" from which one might hope to start, are of little help; they refer to arbitrarily standardized conditions, are influenced to different extents by changes of composition and concentration of electrolyte, temperature, etc., and may be profoundly altered by cathodic polarization, so that not even the original order remains.

In spite of the fact that the numerous complications mentioned above render a quantitative theory impractical, the possession of such theory is a most useful guide. Otherwise, the practical approach becomes a mere groping in the dark. Clearly, by adopting all the expedients likely to lead to convergence of two deposition potentials and by avoiding those that are likely to lead to divergence, the chance of achieving co-deposition is greatly increased.

If alloy deposition is regarded merely as the simultaneous discharge of two cations, it is not essentially different from plating a single metal with simultaneous hydrogen evolution, the con-

* Director, International Tin Research Council.



Fig. 1.—A view of the electroplating laboratory.

ditions then being adjusted to the simultaneous discharge of metal and hydrogen ions (low-efficiency plating).

The alloy plater may well think that his process is rather different, especially when he is depositing an alloy having different properties from those of either single metal. No one has yet seriously developed the idea that a *special* theory of alloy deposition is required in the sense that the alloy itself may have its own electrochemical peculiarities associated with a characteristic deposition potential and over-potential. Nevertheless, this point of view is worth serious study, especially in those cases where the alloy deposited is an intermetallic compound. In some cases it is known that the intermetallic compound is considerably nobler than the constituent metals, and the possibility might then arise that simultaneous discharge of two cations could occur more easily than separate discharge of either. There is at least a prospect that some anomalies might be explained by such a view, particularly the co-deposition of two metals from a solution from which only one of them is capable of being deposited singly. There is scope for an experimental investigation on these lines.

At the Tin Research Institute an endeavour has been made to use as much as possible of the background knowledge described above, particularly taking advantage of the well-known fact that it is generally easier to bring two deposition potentials together when the metals to be deposited are locked in anionic complexes than when they are present as simple cations. It has also been found most useful to study cathodic polarization curves and, in some cases, to measure conductivities and

This practical approach has taken the fullest advantage of all that can be learned from planned series of tests in the Hull cell, in which the anode is placed in a position at right-angles to two parallel sides of the cell, while the test cathode is placed at a fixed angle to the anode. The result is that the cathode current density varies logarithmically over the cathode from a high value at the end nearest the anode to a low value at the end remote from the anode. In this way a wide range of current densities can be covered in a single experiment. The experienced research worker soon derives a considerable ability to judge the plating qualities of an electrolyte merely by visual examination of the Hull cell plates, and by chemical analysis he identifies regions of alloy deposition.

When it has at length been established—perhaps after many changes of anion, variations in concentration and temperature, and trials with different addition agents—that alloys have actually been deposited over a certain range of current density, the next stage of the work becomes concentrated on two immediate objectives. One is to determine more precisely the composition range of alloys that can be obtained and how composition varies with the many different conditions of electrolysis; the other is to examine the properties of the deposits and to decide whether those of a certain composition are likely to be useful or interesting.

At this stage yet another factor begins to enter: it may be found that the practical conditions for depositing an alloy of certain composition vary to some extent with the size and geometry of the electrolytic cell on account of the changed current

Fig. 2.—W... of electro...

distributi... possible... the initia... in a larg... be gain... of the pr... At the T... is usual... Hull cell... a 40-lit... manyth... of work... fidence... larger-sc... litre cap... is satisf... these lar... which r... it is gen... industry... During... ment, I... multitu... pure th... For exa... current... the cho... metals;... brightn... solution... accumu... the inf... tamina... substan... not on... relatio... which

The... Tin R... in pub... out of... here... vation... remar... All... which... it mus... be co... soluti... consi... An... binati... cyan... depos... and s...

Fig. 2.—Work in progress on a study of electrode processes in alloy plating.



distribution. In general it is impossible to proceed directly from the initial Hull-cell tests to a trial in a large tank. Experience may be gained by increasing the scale of the process one step at a time. At the Tin Research Institute it is usual to graduate from the Hull cell to a 4-litre bath, then to a 40-litre tank, and only after many thousands of ampere-hours of working can there be confidence in proceeding to larger-scale trials in tanks of 800-litre capacity. When a process is satisfactorily under control in these large tanks—a trial period which requires many months—it is generally ready for use in industry.

During the course of these stages of development, practical observations are made on the multitude of important factors with which the pure theory of alloy plating is not concerned. For example, the behaviour of anodes as regards current efficiency, sludging, evenness of attack, and the choice between alloy anodes or the separate metals; the adherence, covering power and brightness of the deposit; the stability of the solution towards oxidation or hydrolysis and the accumulation therein of harmful by-products; the influence of small amounts of organic contaminants or of intentionally added organic substances; the "throwing power" of the deposit not only in relation to thickness but also in relation to composition; all these are factors on which the acceptance of a new deposit depends.

Some Tin-alloy Electrodeposits

The various tin-alloy deposits devised at the Tin Research Institute have been fully described in publications of the Institute and it would be out of place to describe details of the processes here. On the other hand, certain general observations may be found useful in illustrating the remarks made above.

All the following notes refer to plating baths which are either in use or are practically possible; it must be realized that many pairs of metals can be co-deposited in the laboratory from certain solutions under conditions which could not be considered as a practical proposition.

An important group of solutions is the combination of an alkaline stannate with a complex cyanide. For example, *tin-copper alloys* are deposited from a bath containing sodium stannate and sodium cuprocyanide. There are two useful

ranges of composition; one a red bronze containing from 10 to 15 per cent of tin and the other "speculum," a silvery alloy containing 42 per cent of tin and consisting of intermetallic compounds of tin and copper. Both these coatings are in commercial use. In the same group is *tin-zinc alloy*, deposited from sodium (or potassium) stannate and sodium-zinc cyanide. Coatings containing 75 per cent of tin and the balance zinc are widely used in many countries as a protection for steel in aircraft, motor-car parts, refrigerators, etc. Other metals can be co-deposited with tin from this type of solution, but these further processes have not won commercial acceptance. In all of these solutions tin is present in the quadrivalent form in an anionic complex.

The fluorides provide another group of electrolytes in which bivalent tin forms an anionic complex as SnF_4^- . The now commercially available *tin-nickel alloy* is deposited from a solution of stannous and nickel chlorides containing sufficient sodium and ammonium fluorides to complex all the tin as SnF_4^- . This process is particularly interesting because, contrary to the usual experience in alloy plating, a deposit of almost constant composition is obtained which is independent of wide variations of current density, temperature and composition of the solution. The faintly rose-coloured deposit, which is very resistant to tarnishing and corrosion, has a composition corresponding to the formula NiSn and this formula is confirmed by X-ray examination, which shows a single-phase lattice. This is a metastable structure which has not been produced except by electrodeposition; the compound NiSn is not represented in the thermal equilibrium

diagram of the tin-nickel system and, in fact, the electrodeposited NiSn is transformed into a mixture of Ni_3Sn_2 and Ni_3Sn_4 when heated at temperatures above 300°C .

Tin-cobalt alloys can be deposited from a similar solution, but have not shown any outstanding properties. Another interesting alloy obtained from the chloride-fluoride electrolyte is *tin-antimony*, which has good antifriction properties and may prove useful as an electrodeposited bearing surface.

The fluoborates and fluosilicates also lend themselves to the production of tin-alloy deposits. *Lead-tin alloys* and *cadmium-tin alloys* are deposited for industrial purposes from fluoborate solutions. Tin-zinc and other tin alloys can also be obtained from mixed fluoborate-fluoride

There are, however, many other considerations influencing the finish provided by a tin coating. On hot-dipping in the same tin pot after the same pre-treatment, it may be found that one piece of steel acquires a mirror-like tin coating while another takes up a film of tin which retracts into globules while still molten and, after solidification, forms a streaky coating in which lumps of excess tin alternate with areas barely covered.

Under the leadership of W. E. Hoare, some of the problems of hot tinning and the tinplate industry have been studied for many years at the Tin Research Institute and the "de-wetting" phenomenon in tinning has been studied in some detail. It was shown that the trouble lay in the fact that such steels have a thin and often invisible non-reactive skin on their surface, which is quite



Fig. 3.—Part of the installation in the hot-tinning laboratory.

solutions. So far as is known, the tin exists as a simple cation in fluoborate solutions and it is therefore likely that only the metals near to tin in the "electrochemical series" will be co-deposited with tin. The same consideration holds for sulphate solutions, from which it is possible to co-deposit tin and cadmium in the presence of considerable amounts of organic addition agents.

Tinned Steel and Tinplate

When steel is coated with tin, whether by electrodeposition or by hot-dipping, the coating is in general thinner than that used for other protective coatings; in fact, most tin coatings are considerably less than one ten-thousandth of an inch thick. The degree of finish obtained is therefore related to the finish of the steel sheet before tinning. Hence, steel destined for tinplate manufacture is normally given a brilliant finish.

distinct from the usually encountered oxide scale, rust or grease with which the routine methods of preparation are designed to deal. Normal degreasing and pickling methods do not remove this skin, but special treatments for its removal have now been worked out. This peculiar surface condition of the steel is connected with the cold-working and annealing operations to which the steel is subject during manufacture and fabrication. A common factor in the histories of steels of difficult tinning quality is that they have been heavily cold-worked in the presence of lubricants and, more particularly, that a subsequent annealing process has been undertaken without removing the lubricants. Certain rolling lubricants, under the conditions obtaining in low-temperature bright annealing, may become polymerized or oxidized and form lacquer-like or gum-like films, which are not removed by ordinary detergent processes.

There are, of course, other factors influencing the finish of a tin coating, such as the presence of certain elements (e.g. chromium) in the steel and the enrichment of certain elements in the surface layers during annealing. As a result of the research carried out, procedures applicable to all these cases and capable of producing smooth, even tin coatings have been developed. But an even more important result of the work was to show the requirements of a steel surface suitable for tinning so that correct preparative procedures may be adopted at the outset.

On a micro-scale, somewhat similar considerations apply to the manufacture of electro-tinplate. As is now well known, the continuous steel strip passes through degreasing, pickling, and tin plating tanks with their respective rinses and the thin tin coating is then momentarily fused, generally either by electrical conduction or induction heating. This converts the as-plated matt coating into a bright coating and, at the same time, produces a very thin layer of tin-iron intermetallic compound at the tin-steel interface. This change has an important effect on the solderability and the corrosion resistance of the tinplate. When the "flow-brightening" is at its best the corrosion resistance of tinplate is increased, but there are conditions under which the momentarily molten tin coating "de-wets" on a micro-scale and then corrosion resistance may be much impaired. Indeed, it has been said that the best conditions for electrotinplate manufacture are those which produce a tin coating which is flow-brightened with the greatest ease.

These matters have been a subject of study at the Tin Research Institute in recent years and the research is still being pursued. As it is impossible to simulate electrotinplate manufacture by scaling it down to laboratory dimensions, the expedient has been used of inverting the process. In our laboratory model, the tin-containing electrolyte is pumped at the rate of 600 linear feet per minute past a stationary steel strip cathode. The influence of different pre-treatments of the steel, such as controlled pickling and annealing procedures, on the quality of the tin coating can then be studied. But to extend the simulation of the electrotinplate manufacturing process it was necessary to introduce a flow-brightening stage to follow the plating stage.

For this purpose special apparatus was designed in which a piece of as-plated strip taken from the plating stage and cut to 10.5 in. \times 3.5 in. is heated rapidly by electrical conduction for a pre-determined time and then rapidly quenched. The electrical cycle is commenced by pressing the starting button of a process-timer and the temperature of the specimen rises at the rate of about 140°C. per second. In this apparatus the

minimum time for melting the tin coating is about 1.7 seconds, while the bright tin surface becomes oxidized with heating times in excess of 2.8 seconds. With a time of 2.5 seconds the maximum temperature reached by the specimen is about 330°C. and, if other conditions are correct, a high reflectivity is obtained. During this interval, the initial current of 1600 amp. at 8 volts falls to 800 amp. as the temperature rises. The interval elapsing between the breaking of the heating circuit and the total immersion of the specimen in the quenching medium is about 0.2 seconds.

All this equipment is but a means to an end—to achieve the best finish by ascertaining how the finish is related to the history of preparation. In the broader sense, "finish" involves more than appearance and, in the case of thin tin coatings, is related to serviceability. Another side of the question is, therefore, the testing of tin coatings in order to assess serviceability. This is a complicated story which would require a separate article in itself. Here it must suffice to state that, in view of the over-riding importance of the canning industry, the assessment of quality in tinplate is particularly concerned with corrosion behaviour; that it cannot be expected that a simple test will answer all the many questions at stake; and that the Tin Research Institute has made and is making useful contributions in this field, many of which are already available in published form.

Corrosion Studies

The Corrosion Department, which for some years has been led by S. C. Britton, plays an essential part in all the researches on coatings of tin and its alloys. Much of its work consists in testing, but it is not difficult to select examples of applications of metal-finishing interest arising directly from the working of this department.

It was shown, for example, that a thin tin coating on steel is a very good base for paints of widely divergent types. This is particularly evident on exposure to atmospheric weathering or other mildly corrosive conditions, when the combination of tin plus paint gives more protection than would be expected from the sum of the two coatings. The remarkable reproductions of works of art on tinplate boxes are a reflection of the compatibility between tin and paint. In some industries, particularly those concerned with sheet metal, tin coatings or tin-zinc alloy coatings are being applied to the sheet to derive the combination of paint holding and corrosion resistance. This practice will undoubtedly increase now that "electro-tin," a heavier-gauge steel sheet coated lightly with tin, is becoming commercially available in the United States.

B • • I • • F A Short Survey of Some of the Items of Metal Finishing Interest on Show at Castle Bromwich

THIS year's British Industries Fair is the first to be held under the aegis of the new independent organization, although the engineering and hardware section staged at Castle Bromwich, continues, as in the past, to be the responsibility of the Birmingham Chamber of Commerce. Naturally insufficient time has elapsed since the take-over of the Fair organization for any significant changes to have been made and consequently the arrangements all-round differed little from those in previous years.

It is perhaps appropriate to express here some criticism of the attitude of exhibitors to the arrangements made in connexion with the press preview of the Exhibition. This function is always staged on the Friday previous to the Monday opening of the Fair, and a substantial number of representatives of all the leading trade and technical journals are brought to the site and afforded facilities for viewing stands, taking photographs, and discussing exhibits with the stand holders. Unfortunately however, this opportunity of obtaining publicity for their exhibits attracts very little support from exhibitors and nearly three-quarters of the stands are normally either screened from view or incomplete, and only a minority of them is manned. There may indeed, be many effective reasons for this state of affairs and it should be a matter of priority to those responsible for the organization of the Fair to make a full review of the general press-viewing arrangements, taking fully into account the wishes and proposals of exhibitors in this respect.

The general impression gained from a visit to this year's Fair is that considerably more attention appears to have been paid to the design and layout of the stands and of the presentation of exhibits, and although floor space appeared to be less crowded than in previous years, there was in general an air of freshness of approach about most of the displays.

Dealing more particularly with items of interest to the metal-finishing industry, these were as usual scattered over the four principal sections of the show, and anyone particularly interested in studying equipment and materials for painting, electroplating, galvanizing and vitreous enamel-

ling, would consume no small amount of shoe leather in attempting to achieve a comprehensive coverage.

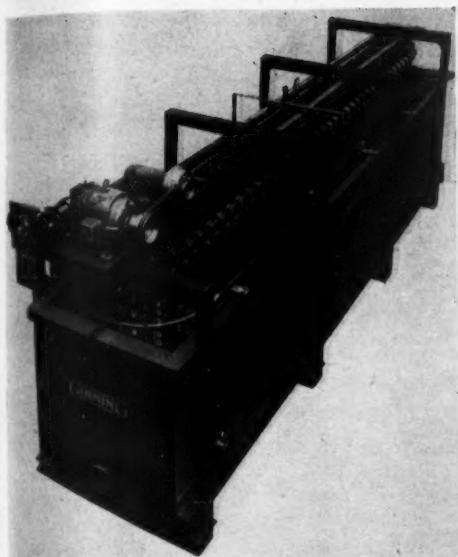
Nevertheless, there was much of interest to be seen, including several new items, and although space may preclude detailed descriptions of many of them in the course of this brief survey, they will be more fully reviewed in the appropriate section of subsequent issues of this Journal.

Electroplating

Only a very few contract electroplaters exhibited; these included **Ionic Plating Co. Ltd.**, **Renu Plating Co. Ltd.**, **Fescol Ltd.**, and **Poeton Industrial Plating Co. Ltd.** A miniature transfer plating layout exhibited on the stand of **Ionic Plating Co. Ltd.**, depositing cadmium on single wood screws aroused interest, although the company was at pains to point out that their massive output of plated screws was not achieved by such methods. A particularly attractive exhibit on this stand was two sets of chess-men moulded in plastic to a French design and plated in gold and silver. **Fescol Ltd.**, showed examples of the hard chrome deposits for which their name has become well known, a large hydraulic ram, being a particularly striking example.

Among the suppliers to the industry there were a number of interesting and comprehensive exhibits. The full range of polishing equipment and materials manufactured by **John Hawley and Co. (Walsall) Ltd.**, was on show, including a new range of air-cooled bias wheels and sections impregnated with polishing compositions.

W. Canning and Co. Ltd., showed their new developments of the last twelve months, together with a cross-section of their normal wide range of equipment and materials. The main exhibit was a Rotamatic plating unit, incorporating in its driving mechanism, a new development. This supersedes the earlier principle of the Rotamatic whereby work is circulated through the plating electrolyte at a constant speed predetermined to produce a specified plating thickness by causing the work to reverse its direction of travel for a short period. For example, by this system, known as the "pilgrim step" movement, work can travel



A typical Rotamatic plating plant which may incorporate the 'Pilgrim Step' movement.

forward two feet and then backward for one foot, a net forward travel of one foot. This sequence takes the same amount of time as would be required for one foot forward travel in the normal circuit. However, it is claimed that the increased mechanical movement of the cathode through the solution results in superior quality of deposit.

Among items featured on the stand of **Electrochemical Engineering Co. Ltd.**, was the **Efco Di-Phase** cleaning system. Di-Phase cleaners consist of two immiscible liquid phases of differing densities which are made to contact the work simultaneously. This is achieved either by dipping the work through the upper solvent layer into the lower emulsion phase, or by spraying the work with streams of both phases together.

The solvent phase consists of a hydrocarbon solvent incorporating certain auxiliary solvents plus free fatty acids. This phase will dissolve oil-soluble soils such as petrolatum, lanolin, lubricating and cutting oils, etc. The emulsion phase comprises an emulsion of solvent in water, combined with soluble soaps, wetting agents and dispersants. This phase will dissolve water-soluble compounds such as brazing residues, and the inorganic salts deposited by fingerprints.

In addition to the purely solvent actions of the two phases, there is a selective wetting and dispersion effect exhibited by each phase towards oleophilic and hydrophilic insoluble soils respectively.

Another new item exhibited on this stand was a

cluster plating barrel suitable for the barrel plating of small components in small lots.

R. Cruickshank Ltd., featured as a new introduction their "New Sheen" barrel polishing equipment, two models of which, of latest design, were on show. Specimens displaying their new bright cadmium plate and bright bronze plate also attracted interest.

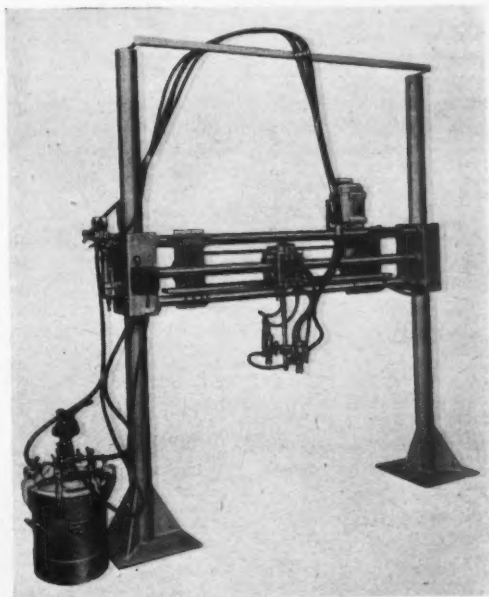
The range of polishing and plating, plant and materials manufactured by **Silvercrown Ltd.**, on show on their stand, included among new developments bright Nিকেlex and bright zinc and cadmium.

Among the examples of new research developments exhibited on a stand sponsored by **D.S.I.R.**, was the non-destructive plating thickness gauge recently developed by the **British Non-Ferrous Metals Research Association** and described in this Journal (*cf. Metal Finishing Journal*, 1955, April, 1, (4), p. 145).

Paints and Painting

The stand of the **Aerograph Co. Ltd.**, was this year larger than previously and showed a comprehensive range of spray finishing equipment. Particularly featured was an automatic transverse spray-coating machine, particularly suitable for the rapid finishing of articles on a mass-production scale. Available in two models, the Mark III with a fixed traverse speed of 300 ft. per min. and

Automatic transverse spray-coating equipment featured by the Aerograph Co. Ltd.



the Mark IV with infinitely variable traverse speed ranging from 35 to 420 ft. per min. this equipment exhibits considerable versatility. The distance of traverse on the standard machine is variable between 2 and 6 ft. although special machines can be constructed for use outside this range in special circumstances. The equipment is suitable for the application of all standard finishes, hot-spray finishes, vitreous enamels, strippable coatings, rust preventive coatings and resin adhesives. Other exhibits included an improved water-wash spray booth, and a circulating system for the supply of paint to spraying points.

An interesting development in spray application was shown by **Alfred Bullows and Sons Ltd.**, in the form of a two-gun-head catalyst spray gun for spraying epoxy resins, polyester resins and any similar combination of incompatible fluids, which are unstable when mixed together. The gun comprises two separate gun heads independently fed and separately metered, whereby the fluids are not mixed until they leave the gun.

Among the fifteen or more exhibitors showing paint products there were several featuring industrial finishes based on epoxide resins. For example, on the stand of **Cellon Ltd.**, Cerrux industrial finishes based on epoxide and vinyl resins for general industrial metal finishing applications were shown in varying forms according to manufacturers requirements. These included formulations suitable for air-drying or stoving, hot or cold spraying, and dipping, and resistant to attack by most chemicals, solvents, alkalis and detergents.

Another interesting development was "Celletch" self etching primer in a range of tints, which provides an economic method for producing a high gloss coating in only two coats in white, blued-white or ivory.

Particular emphasis on the use of epoxide-resin based paints for domestic equipment and industrial plant was also noticeable in the range of exhibits shown on the stand of **General and Industrial Paints Ltd.**

There was very little representation at the Fair of metal pre-treatment processes, the most notable being the stand of **E. Spiero Chemicals Ltd.** who demonstrated a fully automatic plant for degreasing, cleaning, rust removal and phosphating, together with examples of processed work, and the other metal preparation and finishing products of the company.

On the stand of **Metal Processes Ltd.** examples of the company's immersion metal-colouring treatments were displayed, including the Mk. II black finish for steel, and Niklit silverbright finish for brass and copper, as well as a wide range of processes for treating aluminium and

zinc alloys, and for degreasing and rust removal.

Other Finishes

Among the other finishes normally applied to metals, the strongest representation was among the aluminium anodizers, and some particularly effective examples of coloured finishes on aluminium, gold being the most popular, were on show. Noteworthy in this connexion were the stands of **Coloral Products Ltd.**, **The Midland Metal Spinning Co. Ltd.**, and **Dohm Ltd.** The exhibits on these and other stands revealed that the standard of finish obtainable by modern processes on properly selected aluminium alloys can be very high indeed and would indicate that the continental trend now evident of substituting chemically brightened super-purity aluminium for nickel-chromium plate in certain applications may well find support in this country.

While a considerable amount of vitreous-enamelled ware was on display in the hardware section of the Fair, there were virtually no exhibits of vitreous enamelling supplies. The only representative of this class was the exhibit of **Metal Porcelains Ltd.**, displayed on the composite Smethwick Industrial stand.

A number of firms specializing in galvanizing to the trade, or in the marketing of galvanized ware staged exhibits, while for the benefit of those seeking to install galvanizing equipment for their own use there was an interesting exhibit highlighting their proficiency in the supply of this equipment on the stand of **Thompson Bros. (Bilston) Ltd.** Examples of architectural iron work, rust proofed by the Sherardizing process were displayed on the stand of **Zinc Alloy Rust-proofing Co. Ltd.**, which also acted as a technical information centre on the applications of the process.

Automatic and manually operated metal spraying equipment by the wire process was shown on the stand of **Metallization Ltd.**, together with examples of application of the process.

Plant and Equipment

There were numerous exhibits of plant of interest to the metal finishing industries on show in addition to the specialized equipment already referred to. For example **Controlled Heat and Air Ltd.** on the Smethwick Industrial stand drew attention to their range of ovens for tin printing, paints and lacquers, as well as pre-treatment plant and vitreous enamel drying ovens.

Electric Construction Co. Ltd., featured plating rectifier equipment as also did the **Westinghouse Brake and Signal Co. Ltd.**, who showed, among many other exhibits, a typical heavy-duty rectifier power plant for an anodizing installation with a fully automatic programme controller.

(continued in page 230)

Lack of success in passing examinations arises almost as frequently from failure to apply knowledge properly as from failure to acquire knowledge. This series of articles is intended to assist actual and intending entrants for the City and Guilds Certificate Examinations in Metal Finishing to answer examination questions in the most effective manner.

Definitions

BEFORE considering the theory of electrolysis, it is essential that a student of the subject should thoroughly understand the definitions of the terms used. It is, therefore proposed to discuss these at some length.

Electron.

As previously stated, an electron is a very small negative charge of electricity. When dealing with very small particles, the question of whether these particles represent matter or energy is not always easy to answer. According to the definition, an electron actually is a certain weight (9×10^{-28} gm.). It is somewhat difficult to visualize such a very small particle, but from the point of view of a candidate in the examination, it will be quite sufficient if he knows that the electron is the fundamental unit of negative electricity and that it carries a small negative charge. He must realize, however, that this particle is so small that it can penetrate through normal matter.

Atom.

An atom is the smallest particle of an element (for example, a metal such as copper or zinc) that can exist as such. The atom itself is built up of a positive nucleus around which a number of electrons revolve. The number of electrons in question and the value of the charge on the nucleus will depend on the element. As the atomic weight increases, so more and more electrons circulate round the central nucleus.

Some of these electrons may be temporarily detached from the system and in this case the atom gains a positive charge. It then becomes an *Ion*.

An ion is a charged atom or group of atoms. That is to say, it may be an atom of a metal which has lost one or more electrons, or it may be an atom or group of atoms of non-metals, which has gained one or more electrons. For example, if a substance such as copper sulphate, which is made by combining one atom of copper, one of sulphur and four of oxygen, is dissolved in water, it will be found that it breaks up, giving a copper ion

A Students Guide to Examination Courses in Metal Finishing

II. INTERMEDIATE

Compiled by **A. ALEXANDER**

(Series continued from page 182, April, 1955)

which is, in fact, a copper atom, but having two electrons less than the normal quantity and a sulphate ion which is composed of an atom of sulphur combined with four atoms of oxygen, and having two electrons more than the number for this group. Thus the two ions each carry two charges, a copper ion being positively charged and a sulphate ion being negatively charged. If a potential difference is applied to two electrodes immersed in a solution of these ions, they will move under the influence of the electric current as previously mentioned when discussing electrolytic conductances.

Molecule.

A molecule is the smallest particle of a material which can exist in the free state. Thus, for example, a molecule of copper sulphate will contain one atom of copper, one of sulphur and four of oxygen. In many cases it will also contain loosely combined, seven water molecules, that is to say, fourteen hydrogen and seven oxygen atoms. When dealing with an element, for example, hydrogen, it may be present as an atom of hydrogen which is the smallest particle of hydrogen which can exist as such. If in some way this atom is cut in half, it would no longer be hydrogen. An atom of hydrogen, however, cannot exist as such in the free state, and in fact two atoms of hydrogen always combine together to form a molecule of hydrogen. This molecule can exist as such and normally exists as a gas, hydrogen gas being composed of molecules of hydrogen and not atoms of hydrogen. When a hydrogen ion is liberated at an electrode, it first forms an atom of hydrogen, after which two such atoms combine to form a hydrogen molecule. These molecules are then released in the form of a bubble of gas. It is important for the student to realize the difference between the atom, the ion and the molecule. For example, hydrogen in the atomic state is much more active than it is in the molecular state. Atomic hydrogen will often diffuse into metals and produce changes in their properties. In some cases also, there may be a certain time lag in the

formation of the molecule and this may tend to increase the electrode potential at which the action is taking place. This, however, will be dealt with later.

A candidate for the examination is expected to be able to define, in his own words, the above terms, and also to be able to discuss their interrelation with one another. It is probable that he will have these terms in the elementary chemistry course.

It is also important that a candidate shall be conversant with the terms used in connexion with an electrolytic cell.

1. *Anode.* The anode is the electrode by which the current enters (or the electrons leave) a cell.

2. *Cathode.* A cathode is the electrode by which the current leaves (or the electrons enter) a cell.

3. *Electrode-potential.* This is the potential difference between the electrode itself and the layer of the solution in which it is immersed and which lies adjacent to it. This could be measured by means of a potentiometer. It cannot be measured by means of an ordinary voltmeter, because the voltmeter takes a certain amount of current and if current is taken from this system the potential will drop. To measure an electrode potential contact is made on to the electrode itself, but in order to ascertain the difference of potential between this electrode and the solution itself, it is necessary to have a second electrode immersed in the solution. It is apparent that the potential of this second electrode must be known because it has to be subtracted from the total reading. Also some type of electrode system is needed whose potential is reasonably constant. For this purpose, therefore, it is usual to use a calomel half cell. This apparatus (Fig. 6) consists of a small glass cell with a glass side tube. At the bottom of the cell is a small quantity of mercury, to which contact can be made by means of platinum wire. On top of this mercury is a layer made of mercurous chloride (calomel), saturated with potassium chloride. The cell is then filled with saturated potassium chloride and the end of the side tube is dipped into the solution in which the electrode, whose potential it is required to measure, is immersed. If the static potential of the electrode is required, that is to say when there is no current passing through the cell then the end of the calomel electrode can be dipped into the cell at any place, but if it is desired to measure the potential while current is flowing, the end of the side tube of the calomel half cell must be arranged as near the electrode surface as possible.

The potential between the calomel cell and the electrode is then measured and the potential of the calomel cell subtracted from the electrode element, leaving the potential.

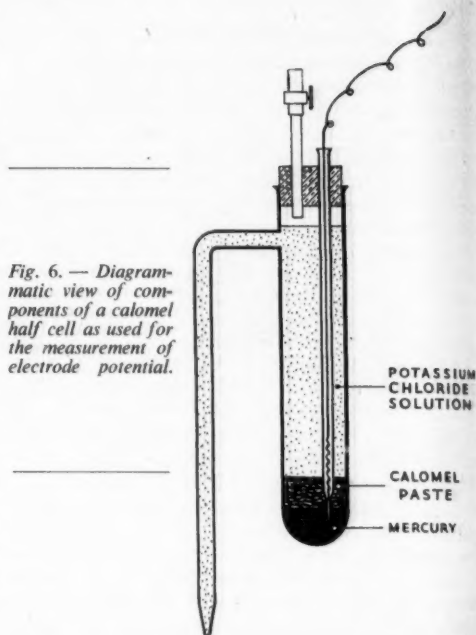


Fig. 6. — Diagrammatic view of components of a calomel half cell as used for the measurement of electrode potential.

The potential of a piece of metal immersed in a solution of its own ions, will be a function of the concentration of the metal ions in the solution and the temperature. This could be calculated but this calculation is hardly within the scope of an Intermediate student and comes in the syllabus for the Final examination.

Electrochemical Series.

If a number of different metals have their potential measured in a solution, normal with regard to the metal ions, it will be found that the metals can be arranged in the order of their increasing potential. This order is called the "Electrochemical Series". If the metals are arranged so that the metal with the most negative potential (magnesium) is at the top, and the one with the most positive potential (gold) is at the bottom, then this order gives a valuable indication of how metals will behave when in contact with one another, or when immersed in a solution containing the salt of another metal. For instance, if a metal near the top of the table, such as zinc, is placed in a solution of copper ions, for example a solution of copper sulphate, the zinc will go into the solution and the copper will deposit on the zinc surface. If two pieces of metal, such as zinc and copper, are riveted together, and if these two are immersed in a corrosive solution (for example, sodium chloride) the zinc will dissolve and the copper will not. If instead of riveting the two

plates together, they are connected through a galvanometer, a current flows between them while the zinc is dissolving, the current flowing from the piece of copper to the piece of zinc and then through the solution from the zinc to the copper. This is the basis of a number of corrosion phenomena and it is, therefore, desirable that a candidate for the examination shall be able to place the commoner metals in the order in which they appear in the Electrochemical Series.

TABLE I.
Electrochemical Series

Magnesium
Aluminium
Zinc
Cadmium
Iron
Cobalt
Nickel
Tin
Lead
Hydrogen
Copper
Mercury
Silver
Gold

It must be realized that this order may vary somewhat according to the conditions under which the potential is measured, but the order shown in Table I represents the order in which they will commonly be placed. Both the order in which they appear and the significance of their place in this Table should be memorized.

Polarization.

There is often some confusion in this term, because the terms cathode potential and cathode polarization are often used synonymously. The potential of an electrode (either cathode or anode) has already been defined and represents the potential difference between the surface of the electrode and the solution adjacent to it. The polarization of an electrode is not quite the same thing. In point of fact, it should be defined as the increase in potential over the normal static potential of the electrode.

If a current is passed through an electrolytic system an effect is produced such that a metal is deposited on the electrode or some chemical change is produced on the surface of the electrode, or in the solution adjacent to it. This change tends to produce an opposing potential to that which is applied and this increases the potential necessary to pass a given quantity of current. If the passage of the current is interrupted for a short period it will be found that the electrode will have a greater potential than normal, and its potential will gradually fall to its normal static value over a

short period of time. This increased potential is due to the fact that the products of the reaction which is taking place have a tendency to revert to their original state. Thus if a metal is being deposited at the cathode, the layer of the solution immediately adjacent to the electrode surface tends to become depleted in metal ions. This means that more energy is required to deposit the metal and the potential as a result, rises. If the current is then interrupted the metal has a greater tendency to go back into the solution than it would normally have, because there being less metal ions adjacent to it there is a tendency for it to re-dissolve until the concentration of metal ions becomes constant. After a short space of time some of the metal will probably have redissolved into this layer, while the concentration of the ions will also have been brought up to the original value by the diffusion of further ions from the body of the solution, and the potential will then revert to its original figure. It is important to be able to distinguish between the polarization of an electrode and its potential, and these two terms should not be confused.

In some cases also, polarization takes place due to films of gas or insoluble salts on the surface of the electrode. The result of this is to produce a very much higher voltage between the electrode and the solution than the normal.

Decomposition Voltage.

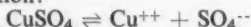
If a normal electrolytic cell has applied to it a very small potential difference across the electrodes, no current will flow. If the voltage across the two electrodes is very slowly raised, then at a given voltage, depending on the cell in question, current will start to flow continuously. This voltage is known as the decomposition voltage of the system in question, and is the minimum voltage required to produce a continuous flow of current.

In any system it is necessary to have a certain minimum potential difference before a current will flow. And at any electrode a certain minimum potential is required before a particular action will take place. If, for instance, a solution contains both copper sulphate and zinc sulphate, and in this solution two electrodes are placed, then a low current flowing through the system will produce only a small potential difference between the solution and the electrodes, and at the cathode only copper will be deposited, because the potential difference between the solution and the electrode is insufficient to deposit zinc. If the current is steadily raised, the potential of the cathode will also be gradually raised and there will become a time when a certain amount of zinc will be deposited with the copper. Normally the metals will deposit out in the order in which they

appear in the Electrochemical Series, but this order may be varied in certain circumstances.

Electrolysis of Simple Metal Salt.

It is now appropriate to consider the electrolysis of a simple metal salt, for example, copper sulphate. This salt is normally obtained in the form of blue crystals and contains a certain amount of water of crystallization, that is to say, loosely combined water. If the material is dissolved in water it ionizes, forming copper and sulphate ions. This happens automatically, *i.e.*, it does not require any applied energy, the salt ionizing immediately it is dissolved. The degree to which this reaction takes place is somewhat problematical. The reaction used to be considered as a "balanced" reaction, that is to say, there is an equilibrium between the un-ionized copper sulphate and the copper and sulphate ions, according to the reaction:



The exact method and amount of this reaction is still open to some controversy, and at any rate it is not supposed that a candidate for the Intermediate examination will be familiar with all the modern theories of ionization, neither will he be required to discuss them. For practical purposes it may be assumed that the reaction takes place in the way indicated by the equation, and that there is an equilibrium set up between the amount of ionized and un-ionized salt in the solution. This equilibrium may often be expressed by what is called the "ionization constant", which represents the ratio between the ionized and un-ionized material.

In an electrolytic cell containing a solution of copper sulphate with an addition of a certain amount of free sulphuric acid to prevent the formation of basic salts and to assist in the solution of the anode, and if this cell has two copper electrodes immersed in it, the action of electric current passed through it may be studied.

When a sufficient potential difference is applied to the two copper electrodes, the current will flow in the manner previously described. The copper ions will move towards the cathode and when they approach the cathode surface they will gain two electrons each and become copper atoms. The SO_4 ions will move to the anode surface and there give up two electrons. Since this group of atoms cannot exist as such in the free state, it is necessary for it to combine with the copper of which the anode is made to reform copper sulphate.

Since the solution contains a certain amount of free sulphuric acid there will also be present a number of hydrogen ions, but since hydrogen is above copper in the Electrochemical Series, and therefore requires a higher potential than copper

in order that it may be liberated at the cathode atomic or molecular hydrogen will not be formed unless a very high current is passed through the cell.

If the action of the cathode is considered in greater detail, it is possible to visualize the copper ions being discharged at the surface and becoming atoms. These atoms will then proceed to take up their position on the surface of the cathode in regular rows, forming crystals. If the atoms are being released moderately slowly, and if nothing but copper atoms are present in the area, the normal tendency will be for these atoms to form fairly large crystals which will produce a soft ductile deposit. If, however, the atoms are being released very quickly due to the use of a high current, or if there is other material being deposited simultaneously, for example, some organic colloidal matter, either intentionally added or present as an impurity, then there will be a tendency for the crystals to be much smaller because there will not be time for a large crystal to grow, and also the introduction of foreign matter into the growing lattice will tend to break it up and produce a number of smaller crystals. This will produce a harder less ductile metal.

As the reaction proceeds, that part of the electrolyte immediately adjacent to the cathode surface will become depleted in metal ions. Although the metal ions are carried by the current towards the cathode, they move in the solution comparatively slowly. Due to this cause and where a high current is being used their motion due to the potential difference, will not be quick enough to keep up the concentration around the cathode surface. If the temperature is low, the motion will be still further slowed, so that after a time there will be insufficient copper ions to carry the current and some of the current will be carried by hydrogen ions, hydrogen being liberated.

In order to overcome this trouble it is often found necessary to resort to artificial means to keep up the concentration of the copper ions at the cathode surface. If the temperature of the solution is increased, the ions are able to move more quickly because the increase in temperature reduces viscosity (stickiness) of the solution, so that they can move more freely. Since a large part of their motion is due to diffusion rather than migration, an increase in temperature means that fresh ions will diffuse much quicker into the area of low concentration. In practice, however, it is often necessary to increase this action still further by convection, that is to say, by stirring up the solution so as to bring the ions up mechanically. This will still further increase the rate at which the copper can be deposited.

The same general conception applies to the
(continued in page 230)

THE INSTITUTE OF METAL FINISHING

ANNUAL CONFERENCE

Palace Hotel • Torquay

MAY 17-21 • 1955

Conference Supplement

For the guidance and interest of those of our readers who, as members of the Institute of Metal Finishing or as visitors, are attending the Annual Conference of that body, the following pages contain information relating to the arrangements and organization of the Conference, together with very brief synopses of the papers to be presented at the technical sessions.

* * * *

To all delegates their ladies and their guests we wish a happy and successful Conference, while for the benefit of the larger number interested in the work of the I.M.F., but unable to be present at Torquay, our June issue will carry a detailed report of the Conference proceedings and functions.

THE INSTITUTE OF METAL FINISHING ANNUAL CONFERENCE, 1955

FOR this, the sixth residential conference on metal finishing to be held since the war, the Institute of Metal Finishing returns to its 1951 venue, Torquay. In the present state of acute shortage of adequate hotel accommodation, the selection of a seaside or spa resort is one which Conference organizers cannot avoid, and the facilities which are now made available at such centres certainly add considerably to the profit and enjoyment which can be derived from such meetings.

From the experience obtained in organizing such functions in previous years the Institute of Metal Finishing can be assumed to have decided upon the pattern which has the widest appeal to its members and to the industry in general, and the present programme as detailed in the following pages is planned along very similar lines to earlier ones. Support for this policy is indicated by the steadily increasing number of delegates that attend each year and there can be little doubt that the conferences play a very useful role as a technical and industrial focal point to the year's activities.

It should perhaps be unnecessary to emphasize that the value to be obtained from attendance at such Conferences depends, as in so many other instances, on the individual contribution made by each delegate. It is only by full and effective participation in all the functions, both technical and social, that the greatest possible benefit, both to the individuals concerned, and also to the industry can be derived. Technical progress has its roots in research but it is watered by personal contacts and fertilized by free discussion.

Preprints of all the papers to be presented at this Conference have been circulated in advance and will only be introduced briefly by the authors during the technical sessions. As an aid to those attending the sessions, some of the salient points from each paper are abstracted and printed in the appropriate sessions in this supplement. In view of the crowded nature of the programme all contributors to the discussion must necessarily keep their remarks brief, and in this way it is to be hoped that time will be found to give expression to a large number of points of view.

PROGRAMME

Tuesday May 17.

8.30 p.m. Registration at Conference Office, Palace Hotel.

9-10.30 p.m. Show of films of metal finishing interest.

Wednesday, May 18

9.30 a.m. Official opening of the Conference.

9.45 a.m. FIRST TECHNICAL SESSION. Chairman Prof. J. W. Cuthbertson, D.Sc., F.I.M., A.M.I.E.E. The presentation and discussion of papers Nos. 1-3.

Abstract No. 1:

The Effect of Chromium Plating on the Fatigue Strength of Steel.

By C. Williams, B.Sc., A.I.M. and R.A.F. Hammond, B.Sc., A.R.C.S., F.R.I.C.

THE effect of chromium plating on the fatigue limit of EN25(Ni/Cr/Mo) steel in two conditions of heat treatment has been determined. Three thicknesses of chromium (0.001, 0.006, and 0.012 in.) were studied and tests of fatigue limit were carried out on the material unplated, as plated, and after post-plating heat treatment at temperatures up to 620°C (520°C only for the harder steel). Standard Wöhler test-pieces were used; these were degreased, then stopped-off, leaving only the working parallel and the radii exposed, followed by anodic polishing. Immediately prior to chromium plating the test-piece was anodically treated in alkali to remove any superficial grease or tarnish film.

Electroplating was carried out in several different solutions under carefully controlled conditions, and heat-treatment was carried out in a thermostatically controlled oil-bath. The results of the investigation have confirmed much that was already known concerning the effect of chromium plating on the fatigue limit of steel but amplify previous information and, in particular, provide positive evidence of the influence of internal stress in the chromium deposit upon the fatigue limit of the plated steel. In addition light is thrown upon the manner in which the fatigue limit is modified by post-plating heat-treatment.

For EN 25 steels of 65 and 80 tons per sq. in. U.T.S. the actual fatigue limit after chromium plating is independent of the hardness of the steel, and the percentage loss of fatigue strength is greater with the stronger steel. A direct relationship, which is probably linear, exists between the residual internal stress in the chromium deposit and the percentage loss in fatigue limit.

Fatigue failure of chromium-plated components is governed jointly by the residual internal stress of the chromium and the intrinsic fatigue strength of the electrodeposit. A tentative conclusion is that the fatigue limit of normal

hard chromium deposit is 20 to 25 tons per sq. in. The fatigue limit of heat-treated chromium plated steel varies with the thickness of the chromium deposit especially in the range 100 to 300°C, the loss in fatigue strength being greater for thicker deposits. In the "as plated" condition the fatigue limit is largely independent of the deposit thickness.

As regards heat treatment a further reduction in the fatigue limit is produced at 200 to 300°C, but a treatment at about 440°C restores the limit to the "as-plated" level. By heat-treatment at 520°C it is possible with some steels fully to restore the fatigue limit of the plated steel to a value equal to or even higher than that of the basis material.

After heat-treatment variations in the fatigue limit correspond with changes in the internal stress of the chromium deposit resulting from heating, and it is thought that in engineering, applications of hard chromium plating in which the plated area is subject to critical alternating stresses, it is desirable to heat treat after plating at not less than 440°C. If the resulting softening of the deposit cannot be tolerated, or if the mechanical properties of the steel would be adversely effected by heat-treatment it would be preferable to omit heat treatment unless the steel were specially subject to hydrogen embrittlement.

Abstract No. 2:

A Study of Cracking in Chromium Deposits
By H. Fry, B.Sc.

DECORATIVE chromium electrodeposits are generally no more than 0.5μ thick, since they tend to crack at greater thicknesses and then have relatively little corrosion resistance. It is known that striking variations can be caused in the properties of chromium deposits by varying the temperature of deposition, e.g. deposits 1μ thick, and plated at 40° C., tend to crack, whereas cracking is rarely observed in thick deposits plated at 75° C.

In the hope of explaining the cause of cracking the following characteristics have been investigated in deposits applied from a chromium bath of conventional composition operated over a range of temperatures and current densities viz.: the maximum thickness at which deposits remain free from cracks; the number of cracks per unit area and the depth of cracks, both measured in cross-sections at right-angles to the basis metal; the spacing of striations apparent in etched cross-sections; and stress in the deposit as a function of thickness.

All the test deposits were made in a solution of nominal composition 250 gm. per l. CrO₃, 2.5 gm. per l. H₂SO₄, made up from "Analar" chemicals.

No addition other than demineralized water was made to the solutions, the density of which was checked and adjusted at intervals.

Thickness measurements were obtained by microscope on the thicker deposits, and by stripping and weighing the thinner ones. For examination of deposit structures chromium was plated onto mild steel rod cathodes and for the preparation of metallographic sections a portion of the rod was cut out by first dissolving rings of the deposit on either side of the central portion and then cutting through the steel rod. The cut out portion was mounted in a cold-setting resin. Crack depths were measured on a bench microscope of × 600 magnification and the separation of striations was measured at × 1,500 magnifications.

A contractometer was used for the measurement of stress.

As a result of the work carried out it was concluded that striations parallel to the basis metal are associated with cracking in chromium deposits. Striations become wider, crack depths increase and the number of cracks decreases as the temperature of deposition is raised. Cracks and striations disappear at a plating temperature of 75° C.

In uncracked deposits stress is independent of, or decreases with, increasing thickness of deposit. Cracking is not, therefore, due to stress increasing with increasing thickness until the tensile strength of the deposit is exceeded. Before general cracking sets in some isolated cracks appear, and at approximately the thickness at which general cracking occurs the first striation is formed and the mean stress begins to decrease rapidly.

Abstract No. 3:

A New Method of Analysing the Stresses and Strains in Deposited Coatings

By H. J. Pick, B.Eng., Ph.D.

ALL the techniques for measuring stresses in deposited coatings are based on the one principle of forming the deposit on an elastic base, the deformation of which is measured either during or subsequent to deposition. The residual stress present in the deposit after deposition is a function of the geometry and rigidity of the base. In order that the results obtained by different methods of measurement may be compared it has been the custom to express these in terms of the "true stress" which has been defined as "the stress" that exists in the coating when it is deposited upon a rigid incompressible surface, or, for practical purposes, upon a base metal thick enough to undergo no appreciable deformation.

In order to account for the stresses in deposited coatings, it is necessary to assume that some

dimensional changes occur in them subsequent to deposition. It is suggested by the author that these changes may be expressed in terms of a parameter termed the "linear free strain" which is defined as "that strain which a deposited coating would undergo in a direction parallel to the base if it were deposited on an infinitely thin base of no mechanical strength." The linear free strain measures the macrostrains in the plane of the surface of the deposit.

The formula $ex = dp(t+x)^2$ has been derived for

$$dx \quad 6$$

calculating the linear free strain (ex) at any thickness of deposit (x) from the change in the curvature (p) of a strip of thickness (t) coated on one side only, when the Young's Modulus of the base and the deposit are the same. The author has also derived a formula for the case when the two moduli are not the same. The formulae are applicable only in those cases of deposition when the dimensional changes occurring in the deposits take place rapidly compared with the rate of deposition. The application of the formulae is illustrated in the paper by examples taken from experiments with electrodeposited copper and the conclusion is reached that the use of the concept of linear free strain has facilitated the analysis of these experiments.

* * *

2.30 p.m. SECOND TECHNICAL SESSION. Chairman A. W. Wallbank, B.Sc., F.R.I.C. Presentation and discussion of Papers Nos. 4-6.

Abstract No. 4:

The Electrodeposition of Iron-Zinc Alloys

By S. Jepson, (Miss) S. Meecham, M.Sc., and F. W. Salt, Ph.D., B.Sc.

METHODS are given in this paper for depositing iron-zinc alloys of 3 to 90 per cent zinc content from sulphate baths and attention is drawn to the useful properties of these deposits. Under a given set of plating conditions the iron-zinc ratio in the deposit is directly proportional to that in the bath. Lowering either the current density or the pH raises the zinc content of the deposit. Some baths have a levelling action, since bright deposits can be prepared from them on an etched surface. Examples of such baths are:

- (i) $\text{FeSO}_4 \cdot 7\text{H}_2\text{O}$ 248, $\text{ZnSO}_4 \cdot 7\text{H}_2\text{O}$ 8.8, $(\text{NH}_4)_2\text{SO}_4$ 118, KCl 10, citric acid 0.5 gm. per l., operated at pH 1.7, 50° C., 200 amp. per sq. ft. and giving a 6 per cent zinc alloy of 560 D.P.N. hardness;
- (ii) $\text{FeSO}_4 \cdot 7\text{H}_2\text{O}$ 174, $\text{ZnSO}_4 \cdot 7\text{H}_2\text{O}$ 8.8, $(\text{NH}_4)_2\text{SO}_4$ 118, KCl 10, citric acid 0.5 g., Teepol

0.4 ml. per l., operated at pH 1.7, 50° C., 180 amp. per sq. ft. and giving a 60 per cent bright zinc alloy of 350 D.P.N. hardness.

The throwing power of the baths is comparable with that of a bright nickel bath. Pitting can be overcome by using a wetting agent (Teepol or Lubrol W) and operating at high temperature (80° C.) and low pH (<1.8). Under these conditions the deposits are usually matt and light grey in colour.

Alloys with zinc contents > ca. 30 per cent have electrode potentials in N/10 KCl nearly equal to that of pure zinc. In the C.R.L. beaker test, the alloys with zinc contents between 30 and 90 per cent are, in general, more corrosion resistant than pure zinc. Various applications of these alloys are proposed, including their use as an undercoat for paints and chromium plating and for decorative finishes indoors.

Deposition of iron-zinc alloys from chloride baths is dealt with briefly. A matt, corrosion-resistant alloy of 60 per cent zinc content can be obtained, at pH 1.8, 50° C., and 50 amp. per sq. ft., from a vigorously stirred bath of the following composition:— $\text{FeCl}_2 \cdot 4\text{H}_2\text{O}$ 177, ZnCl_2 42, NH_4Cl 100, KCl 15, citric acid 0.5 gm. per l.

A colorimetric method for the analysis of zinc in the presence of iron is described.

* * *

Abstract No. 5:

On the Electrodeposition of Tungsten-Cobalt Alloys from Aqueous Solutions.

By T. P. Hoar, M.A., Ph.D., F.R.I.C., F.I.M., and I. A. Bucklow, B.A.

THE electrodeposition of tungsten and its alloys is of interest because of the corrosion-resistant and heat-resistant nature of the metal; in addition the hot-hardness of tungsten and many of its alloys is an especially attractive feature.

The authors' investigations have been mainly concerned with the deposition of tungsten-cobalt from citrate solutions. Preliminary experiments were made with a Hull cell, but the main experiments were performed with a rectangular glass box 4.5 cm × 4 cm × 11 cm contained in a 600-ml. beaker covered with a polythene lid. The beaker was surrounded by water contained in an outer vessel and heated, the temperature being controllable to within +1° C.

The results of the experiments indicated that sound tungsten-cobalt alloy deposits can be obtained with high tungsten contents in a solution similar to that of Clark and Holt which was an ammonia-containing solution operated at pH 7 and a temperature of 70–90° C with a current density of 2 to 15 amp. per sq. dm. It was found however, that ammonia is not an essential

ingredient can be as low obtained but into improve was also good de experim (adjuste current conditi to 65 solution state) 4 4 to 7 per litre The bearing tungsten cobalt theory deposi metal deposi alterna postula

Abstract

Corros

By S.

EX tin thing with pores. ability but in substa zinc. pheric the T taining layer depos Benn Davie teste close the si were The were were in the

ingredient in the electrolyte and that deposition can be conducted satisfactorily at temperatures as low as 50°C. No marked advantages were obtained with the use of periodic-reverse currents but interrupted d.c. currents produced a definite improvement in the deposits. Moderate stirring was also found to be helpful in the production of good deposits. The general conditions used in the experiments were as follows: pH, 8 to 8.3 (adjusted with NaOH); temperature 50 to 55°C; current density, 15 to 20 amp. per sq. dm. These conditions gave the highest tungsten content (60 to 65 per cent. of the deposit by weight) in a solution containing: tungsten (as sodium tungstate) 40 gm. per litre; cobalt (as cobalt sulphate) 4 to 7 gm. per litre; citric acid, 100 to 150 gm. per litre.

The investigations have also given some bearing on the theories of the mechanism of tungsten deposition simultaneously with iron, cobalt or nickel. Although the "alternate layer" theory can scarcely account for the alternate deposition of tungsten and of the co-depositing metal in layers of thicknesses observed in the deposit microstructure, it is more attractive if alternate monotomic layers of each metal are postulated.

Abstract No. 6:

Corrosion Tests of Tin-Cadmium Coatings on Steel

By S. C. Britton, M.A., and R. W. de Vere Stapoole

EXPERIENCE in the U.S. indicated that tin-cadmium alloy coatings combined something of the non-galling characteristics of tin with an adequate ability to prevent rusting at pores. U.S. experience also indicated a marked ability of the coatings to resist salt-spray tests, but in the atmosphere the coatings were not substantially different from those of cadmium or zinc. A general investigation, including atmospheric exposure tests has been conducted from the Tin Research Institute with coatings containing tin and cadmium produced either as layered deposits of the two metals or as alloy deposits from the acid sulphate bath devised by Bennett, or from the fluosilicate bath devised by Davies, Angles and Cuthbertson. All the coatings tested were deposited on 18-gauge cold-rolled close-annealed mild-steel sheet, and coatings of the single metals which were included in the tests were deposited from conventional baths.

The alloy coatings from the sulphate bath were "semi-bright"; organic addition agents were used in the bath and were also incorporated in the deposit to an appreciable extent.

Tests of alloy coatings from the fluosilicate bath were straightforward comparisons with other materials in common use with the addition of tin/cadmium coatings produced by depositing first a layer of tin, then a layer of cadmium of equal thickness, followed by heating for one hour at 170°C.

The methods of exposure to corrosion were several viz. in industrial, marine and suburban atmospheres, in Torquay harbour (mid-tide position), in the sea at Shoreham, exposure to condensation out of doors, in closed containers to a humid atmosphere containing organic vapours, spraying (intermittent) to salt solution, and intermittent spraying with distilled water in a chamber in which a coal-gas flame was burning.

The main result obtained from the tests was that for outdoor tests where cadmium is relatively short lived, the alloy coatings are no better and may be worse but, where cadmium is good, the alloy coatings are also good and may be better. It was concluded also that tin-cadmium alloy coatings with tin contents up to at least 50 per cent. applied to steel are as well able as cadmium coatings to prevent rusting at pores when freshly exposed to corrosion. In salt-spray tests the alloys retain their ability to protect steel for much longer than do cadmium coatings; this is also true for cadmium coatings over tin, heat treated at 170°C although these remained as layer coatings. In all the marine environments the alloy coatings behave as much like cadmium, although there is a possibility that some alloys will give protection to steel in the atmosphere for longer than cadmium.

In inland atmospheres, fully exposed or sheltered from rain, the alloy coatings give less protection than cadmium coatings of the same thickness. The alloy coatings are more resistant than cadmium to corrosion by organic vapours. Composite coatings of tin with cadmium, including heat-treated but not fused coatings of cadmium on tin, have shown no advantages in out-of-doors exposure over coatings of zinc or cadmium of the same total thickness, except that zinc coatings derived some benefit in marine atmospheres from a thin coating of tin under or over them.

8.30-11.00 p.m. Reception and Dance at the Spa Ballroom by invitation of the Mayor and Corporation of Torquay.

Thursday, May 19.

9.30 a.m. THIRD TECHNICAL SESSION. Chairman: H. Silman, B.Sc., F.R.I.C., F.I.M., M.I.Chem.E. Presentation and discussion of Papers Nos. 7-9.

Abstract No. 7:

The Chemical Polishing of Mild Steel by Hydrogen-Peroxide/Oxalic Acid Mixtures

By A. Hickling, D.Sc., Ph.D., F.R.I.C., and A. J. Rostron, B.Sc.

THIS paper describes an experimental study which has been made of the reactions of mild steel with hydrogen-peroxide/oxalic-acid mixtures, and defines the conditions under which chemical polishing takes place. Three main features have been investigated, viz. the potential exhibited by the metal, the rate of dissolution and the effect on its surface.

Cylindrical and square-section specimens of two types of mild steel which were given similar surface finishes, were used for the tests. For the potential measurements the specimen was suspended by a thin iron wire in the solution under investigation, which was connected to a saturated calomel reference electrode by a siphon of sodium-sulphate solution; this latter was necessary to obviate the introduction into the experimental solution of traces of chloride which were found to have a marked effect. The e.m.f. produced by the combination of the specimen and reference electrode was applied in series with a standard cell to a valve voltmeter which could be read directly to a centivolt.

For measurement of rates of metal dissolution cylindrical specimens were suspended vertically by thin iron wires in 1 litre of reaction mixture which was maintained at $18^{\circ}\text{C} + 1^{\circ}\text{C}$. It was found desirable to have the specimens electrically connected and this was accomplished by hanging them from a single brass bar. Specimens were withdrawn at 10-min. intervals, washed, dried and reweighed.

The results obtained showed that following a rise of potential to $+0.5\text{V}$, the rate of dissolution sinks to a minimum value; this then begins to increase and does so with progressive acceleration until it attains a maximum very high value as the potential drops suddenly to about 0V . The metal is apparently dissolving throughout the whole cycle, the rate varying from a minimum at the high potential when the metal is approaching the passive state, to a maximum at the low potential when the surface is presumably free from protective oxide. A further result from other experiments was that while the period and rate of reaction can be varied considerably by altering the experimental conditions, the amount of reaction per cycle remains substantially constant.

By use of an oscillograph it was shown that at the beginning of the high potential state the metal is covered by a protective ferric-oxide film; this undergoes some process of dissolution and/or reduction and the potential drops usually to the

value for the bare metal, and sometimes to that for the metal in contact with a porous oxide coating; re-oxidation then leads again to the formation of the protective film and the cycle repeats itself.

It is thought that the film formed is not of uniform thickness and probably is weakest at any asperities in the metal surface. The electrochemical dissolution mechanism itself serves not only to direct corrosion to the exposed metal peaks, but to ensure that further removal of oxide takes place in their immediate vicinity, and it is apparent that there is a self-maintained differential dissolution effect which tends towards a smoothing of the surface.

On the theory outlined in the paper the electrochemical dissolution mechanism will automatically lead to smoothing and polishing of the metal surface, but the actual quality of the polish produced in any given set of conditions will depend of the extent to which the electrochemical dissolution predominates over other reactions which tend to etch the metal surface.

It is suggested that some chemical polishing of any metal might be brought about if a compatible mixture of an acid and an oxidizing agent can be realized such that the oxidizing agent can render the metal passive by oxidation of its surface and the acid is such that the oxide layer can be slowly dissolved.

* * *

Abstract No. 8:

The Electrolytic Oxidation of Copper and Copper Alloys in Hot Alkaline Solution.

By S. G. Clarke, D.Sc., A.R.I.C., F.I.M., and J. F. Andrew, B.Sc., L.I.M.

IN this paper results are presented on the anodic coating of copper-rich material under conditions to obtain a film of appreciable thickness for practical purposes. Müller in 1907 used moderately strong caustic soda at 60°C to produce an adherent black oxide coating of appreciable thickness, and later workers (1939) obtained best results with 10-20 per cent NaOH to which was added a little ammonium molybdate to "accelerate" the oxidation and to produce a deeper shade of black. In 1945 two other workers used 12 per cent NaOH at 90 to 100°C with the current density increasing through a 11-min. treatment from 2 to 10 amp. per sq. ft. The authors of the paper finally used 15 per cent NaOH with the addition of 0.1 per cent sodium or ammonium molybdate operated at 85°C . Cleaning of work for treatment consisted of degreasing followed by light pickling, the electrolytic treatment being carried out afterwards at

15 amp. during minutes. The work in water treatment alloys, operating preliminary lytic o content. It was that th and is shade i to take produc further ceases associ and lo pondi operat 0.000) 85°C . limiti copper at a re the o

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15 amp. per sq. ft. The current remains steady during the oxidation period of about 3 to 4 minutes, after which the copper becomes passive. The work is then removed from the bath, washed in water and dried. Details are given of suitable treatments for 70/30 brass and other copper alloys, and also the results of variations in operating conditions. These variations included preliminary immersion in the bath before electrolytic oxidation, and alterations in molybdate content.

It was concluded as a result of investigations that the molybdate plays no part in the process and is only necessary where the deepest black shade is required. The coating formation appears to take place through the initial and continued production of cuprous oxide, part of which is further oxidized to cupric oxide. The coating ceases to grow beyond a stage which is probably associated with a certain degree of compactness and low permeability and the thickness corresponding to this stage is less the higher the operating current density. For practical purposes 0.0001 in. of coating is obtained on copper at 85°C. and 15 amp. per sq. ft. On brass the limiting thickness tends to be lower than on copper, and thus the coating should be thickened at a reduced current density, and then to complete the oxidation at raised current density.

Abstract No. 9:

The Structure and Growth of Electrodeposits and the Modifications Caused by Brightening Agents

By H. Wilman, D.Sc., Ph.D., F.Inst.P.

THE earlier work carried out by Prof. I. G. Finch and others has been extended in much detail in the fundamental case of deposition of silver on to atomically smooth electropolished faces of a single crystal of the same metal. The results have led to clearer conclusions as to the process involved in electrodeposition and the mode of action of brightening agents.

As a result of the work carried out it was concluded that the temperature at the immediate surface of growing electrodeposits is normally high, i.e. up to 600°C. or more, and the crystals grow under conditions resembling those usual in condensation from a vapour. The tensile stresses arising in the deposits are of the same order as in condensed deposits and are similarly reversed by co-deposition of non-metallic material. On a smooth single crystal face extensive twinning soon develops when a characteristic critical current density is exceeded and this leads to random polycrystalline further growth from which a preferred one-degree orientation develops gradually.

Since the surface temperature during deposition must increase with increase of current density, the growth on the individual projections which develop on the deposit must always (in the absence of oxides or hydroxides or other hindrances to surface migration) be of "lateral growth" types relative to the facets bounding the projections, except at very low current density.

The "outward growth" one-degree orientation developed relative to the substrate, at any current density above the critical value, must represent a preferential deposition on the crystals which grow outwardly most rapidly, to less ion-impooverished regions of solutions, i.e. (for not-too-thick deposits) crystals having two or more densely populated faces normal to the substrate and thus the most densely populated atom row (or a densely populated one) normal to the substrate. In particular the often observed {110} orientation appears to be associated with the preferred growth of crystals having two {111} facets simultaneously normal to the substrate. Additional agents such as are used for promoting brighter silver deposits have widely varying effects on the crystal habit, especially in deposits on the silver (110) face, where at 20°C. in deposits up to 10,000 A. thick the presence of CS₂ led to more pronounced twinning, probably associated with some co-deposition of Ag₂ S; thiosemicarbazide caused outgrowth of extensive thin lamellae parallel to the {111} planes of the substrate crystal but without twinning; thiourea caused extensive {111} facets in addition to the (110) tips of the ridges along [110]. Urea caused very strong {111} twinning at 10 ma. per sq. cm. and alone gave development of ridges parallel to [110] at 60°C. and 20 ma. per sq. cm; and finally KCNS caused little change except in the shape and size of the ridges observed at low c.d. Addition agents appear to cause brightening, mainly when they result in smooth facets, which are large, relative to the light wavelength.

The work described in the paper was effected by electron diffraction techniques.

Afternoon free for various social and other activities. See Conference Notice Board.

Friday, May 20.

9.30 a.m. FOURTH TECHNICAL SESSION. Chairman: G. E. Gardam, B.Sc., Ph.D., A.R.C.S., F.R.I.C. Presentation and discussion of Papers Nos. 10-11.

Abstract No. 10:

The Barrel Plating of Screw Threads

By A. W. Wallbank, B.Sc., F.R.I.C., and D. N. Layton, Ph.D., M.Sc.

SCREWS are cheap to buy but very vital in use, and they should be protected at least as well as, and preferably better than, the component parts that they are fastening. In general, however, the finish on screws is either non-existent or poor, but an understanding of the difficulties inherent in the plating of screw threads should make it possible to produce a service performance as high as any other article in commerce.

A manufacturing tolerance is laid down governing the maximum and minimum limits of both male and female threads and the difference between the effective diameters of the maximum bolt thread and minimum nut thread is known as the *allowance*. A better term would be *clearance*. This allowance may be nil in *close-fit bolts* or may be as great as 0.001 in. in the case of *free fit*.

The majority of threaded components are plated in barrels, but it is unfortunately impossible to plate every point of every article in a barrel or a vat with exactly the same thickness of metal, due to the presence of convex surfaces, etc. on the article. This feature of plating is well known but what is not so widely appreciated is the variation in plate thickness between one article and another in a barrel.

Wood screws and self-tapping screws are little effected by the thickness of the deposit, but the main difficulties are on metal threads, and there should, therefore, be a special allowance for plating in the thread dimension. This is opposed by the screw manufacturer who claims that both manufacturer and user must be able to take screws from general store and plate them or use them unplated at will. As a result of this and other factors the cheap plater with his inadequate deposits becomes preferred because he can be relied upon never to give trouble due to dimensional change.

To investigate many of the extant problems the authors commenced a statistical investigation of barrel cadmium plating, the nominal composition of the plating solution used being:

Cadmium (metal) 4 oz. per gal.

Sodium cyanide (free NaCN) 9 oz. per gal.

Caustic soda (free NaOH) 2 oz. per gal.

The current density used was about 4 amp. per sq. ft., the temperature of the solution being 70 to 90° F. (21 to 32° C.). Over 150 barrel loads were investigated with samples of from 25 to several hundred items taken from each load for thickness testing.

The aim of the investigation was to discover those factors which had most influence on the degree of scatter and in particular to determine the variation of standard deviation with:—

1. Type of barrel.
2. Type of work.

3. Average thickness of metal deposited.

Before this programme could be attacked, however, it was necessary to establish how far the variation in the observed average thickness and standard deviation was influenced by:—

1. Size of sample.
2. Method of test.
3. Person performing the test.

Three thickness test methods were used and all the results of average thickness obtained were well within the estimated experimental errors, and no significant difference was found from different operators.

The type of work plated did not have any specific influence on the thickness scatter in a barrel load. In different types of barrels the rate of increase of spread with average thickness is very similar but at any given thickness the spread is highest for unlined barrels.

General recommendations derived as a result of the experimental work are:—

1. That all barrel plating be ordered to specification.
2. That the present indefinite "commercial" grade be replaced by a new low grade in standard specifications which shall be as rigidly enforced as other grades.
3. That the batch average thickness shall be the criterion of barrel plated work rather than the minimum individual average.
4. That a sample of at least ten items be used to assess the thickness of plating in a batch of barrel-plated work.
5. That thickness should be checked while work is plating and the barrel load not discharged until its average thickness is up to that specified.
6. That the Clarke Gassing Test should be accepted as the inspection test for Cd.
7. That methods similar to (6) should be developed for other metals.
8. That the Standard screw thread be made to dimensions that permit application of a batch average thickness of 0.00027 in.
9. That any plating allowance should be sufficient to accommodate the maximum individual average corresponding to the specified batch average thickness plus 0.00005 in.
10. That the plater should be responsible for plating quality only.
11. That a statistical study of dimensional variation of screw threads within existing tolerances should be undertaken.
12. That the barrel plating of metals other than Cd. should be studied statistically.

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Abstract No. 11:

Electroforming in Electronic Engineering

By P. M. Walker, A.U.C.N., N. Bentley, and
L. E. Hall, B.Sc., A.C.G.I.

THE use of electroforming for the manufacture of electronic radar components is becoming widely accepted, the determining factor for its use being the initial cost of the mandrel which is much in excess of that of producing one or two components by other methods. The process is therefore only economical for batch production, the main advantages being accuracy and consistency in dimensions and electrical properties.

Some components cannot be produced by any other method than by electroforming. When the mandrel can be withdrawn mechanically stainless steel is a suitable material for its construction, but where the component is a complicated shape a plastic mandrel is used, the mandrel being removed on completion by means of a suitable solvent. The authors used, for mandrels stainless steel S.80, and Perspex. A surface finish of about 10 μ in. has been found satisfactory on stainless steel mandrels, but on the non-conducting, non-withdrawable types great care must be taken to ensure that no metallic inclusion remain embedded in the surface.

Stainless-steel mandrels are prepared in the following sequence; jig to rotary cathode adapter; degrease; swill in distilled water; dip in 50 per cent HCl; swill, silver plate (periodic reverse current); swill; cyanide copper plate; repeat the first six operations; place in copper sulphate plating bath; swill; transfer to cyanide plating bath.

For the plastic mandrels the sequence is: assemble machined details (previously silver plated) to mandrel; degrease; swab with detergent; swab with sensitizing solution; swill; apply reduction silver coating; swill; strip back a distance of $\frac{1}{8}$ in. of the masking on the machined details; silver plate (periodic reverse current); swill, cyanide copper plate; wipe with methylated spirit; spray with graphite; polish surface with dry cotton wool; assemble metallic machined details making connexions to each; place, after masking as required, in copper plating bath; swill and transfer to cyanide copper bath. It is essential to exercise care in the machining and pre-treatment of the mandrels, and to carefully control solution composition and the conditions of deposition. Special attention must also be given to plant design including source of current supply and methods of agitation. In normal plating-shop conditions condenser discharge timing mechanisms are not very satisfactory, greater reliability being obtained from mechanical timing.

Stress measurements show that the initial

surface condition affects the final stress figure of subsequently applied electrodeposits, and the use of periodic reverse current reduces the final stress figure compared with normal d.c. plating. In the case of silver cyanide solutions the concentration of carbonates over a considerable range has no effect on the stress in the deposit.

2.30 p.m. FIFTH TECHNICAL SESSION. Chairman: A. A. B. Harvey, M.Sc., A.R.I.C. Presentation and discussion of Papers Nos. 12-13.

Abstract No. 12:

The Electron Microscope in the Study of Paints

By N. D. P. Smith, B.Sc., A.Inst.P.

DUE to the ever-widening use of the electron microscope it is not surprising that the instrument has found its way into the paint industry. The paper commences by giving a brief account of the theory of the electron microscope and the special specimen techniques that are employed, and also describes a method of mounting pigments and a surface replica technique for the paints.

One of the earliest applications of the microscope in the paint industry was to the study of particle size and shape characteristics of pigments and extenders. It has also proved valuable in studying problems concerned with the surface texture of paints, for example, gloss, "bloom" and surface changes during weathering.

The paper also describes the use of thin sectioning techniques in the study of the location of pigment particles in paint films.

Many illustrations are included in the paper.

Abstract No. 13:

The Blistering of Paint Films on Steel Surfaces

By A. Nicholson and H. A. H. Jenkins

BLISTERING of paint can occur only as a loss of adhesion between the paint film and the surface to which it is applied, and therefore adhesion is a property of the paint-steel interface. No significant change can occur at this interface of such a nature as to interfere with adhesion except through the action of some outside agency of which the commonest is water, which attacks the interface through the paint. It has been found that when a paint film is immersed in an aqueous solution, both water absorption and water transmission depend upon the vapour pressure of the immersion medium. It is also found that these properties of the paint

film depend upon the osmotic pressure of the immersion medium, since both vapour pressure and osmotic pressure of a solution are measures of the lower free energy or activity of the solvent molecules in the presence of solute.

When blistering is brought about by the expansion of paint on the absorption of water, separation occurs between the paint and the surface to which it was applied. The blisters are usually apparently empty and they tend to be relatively slow to form. After formation they do not tend to increase in size and they are partly eliminated on drying.

The characteristics of blisters caused by corrosion are that they tend to be irregular in shape and irregular in distribution and can be quite large. They occur usually when corrosion is well advanced and continue to grow progressively until the paint is degraded to the point of rupture. "Snail-track" blistering can occur on phosphate-coated and painted material, taking the form of lines of minute blisters between paint and metal. These blisters have been shown to be caused by osmotic effects, and there is a relationship with the final rinse during phosphating. More recent experiments have shown that deposits of foreign matter beneath a paint film on a steel surface can give rise to blisters by acting as sources of osmotically-active materials, as stimulators of corrosion and as areas of inferior adhesion. The thickness of the phosphate coating has no significant effect upon the onset of blistering, and great benefits result from the incorporation of phosphoric acid in the chromate rinse.

7.00 for 7.30 p.m. Conference Banquet and Ball at the Palace Hotel.

Saturday, May 21

9.30 a.m. 6th Technical Session. Chairman: E. A. Ollard, A.R.C.S., F.R.I.C., F.I.M. Presentation of Paper No. 14 and general discussion on "Education for the Metal Finishing Industry."

Abstract No. 14:

Metal Finishing - Technique or Technology

By the Right Hon. the Earl of Halsbury,
F.R.I.C., F. Inst. P.

THE economic and industrial survival of this country depends on the development of new techniques and products, which entails training of men who will be responsible for them, and also training of men as trainers. Present expansion of University facilities would appear to be adequate for production of scientists and research workers but a serious and growing shortage exists

of technicians and technologists and of facilities for their education. This stems principally from the lack of adequate financial support for technical and technological education, which can largely be blamed on apathy, both within and without industry. In industries such as metal finishing the number of potential students available in the locality covered by technical colleges is not great and local education authorities are not keen to make maintenance grants to technical colleges not located in their district, and thus nationally conceived courses in special subjects can in practice draw only on the local pool of students. There is no metal-finishing industry on a national scale sufficiently co-ordinated to organize and finance provision for the trained manpower of the future.

Under the present plans for higher technological education the necessary legislation has been passed and the administrative machinery exists, but in the absence of sufficient outside pressure, money to further the post-war expansion plans has not been voted.

The major issues have been obscured by such minor controversies as the form of recognition to be granted by technical colleges and the degree of independence which they may enjoy. These are however, incidental to the main theme and the value of a technical diploma granted by a technical college must be established in the eyes of industry before it can claim equal weight with a University degree.

Ladies' Programme

Arrangements have been made for a number of functions for the entertainment of ladies during the technical sessions, although the exact nature of the events will be controlled in many instances by weather conditions. In order to familiarize themselves with the day-to-day arrangements for their benefit ladies are urged to study the Conference notice board where full particulars will be posted from time to time. Tentative arrangements are as follows:

Wednesday, May 18, afternoon: Coach or sea trip.

Thursday: May 19, morning: Mannequin parade; afternoon: Coach or sea trip; evening: visit to Dawlish.

On Friday, May 20, weather permitting members and their ladies will assemble near the Hotel at 1.00 p.m. for the Conference photograph.

Particular attention may be drawn also to the many municipal facilities which may be enjoyed free of charge by invitation of the Corporation of Torquay for the benefit of Conference delegates and their ladies.

FINISHING POST

A SELECTION OF
READERS' VIEWS COM-
MENTS AND QUERIES ON
METAL FINISHING
SUBJECTS

Advice on all aspects of metal finishing practice is offered on these pages, and while every care is taken to ensure the accuracy of information supplied no responsibility can be accepted for any loss which may arise in respect of any errors or omissions.

Contamination of Zinc Bath

1153. Our zinc solution is producing a greyish dull type of deposit instead of the brightish white deposit which we obtained when it was first made up. The solution is a normal type cyanide zinc and we are not employing any special addition agents. We do not require the deposit to be fully bright but would like it to be whitish in appearance.

The trouble appears to be due to contamination from the solution, probably by one of the sulphur metals, for example, lead or copper.

Lead can easily be removed by adding a small quantity of sodium sulphide to the solution, both lead and copper may be improved by adding zinc dust. We would suggest that in the first place you add 1 oz. per gal. of zinc dust to the solution, stir it, allow it to settle and then filter. If this does not produce the desired result an addition of $\frac{1}{2}$ lb. of sodium sulphide per 100 gal. may be tried. This should be added carefully in the form of a solution.

Blistering of Plated Zinc-base Die Castings

1156. We are experiencing considerable trouble with the blistering of plated zinc-base die castings. These castings are being plated first with copper and then with nickel and finally chromium. Quite shortly after plating, within a week at most, a number of small blisters appear on the surface. The castings themselves have been newly made and have not been subjected to corrosive conditions. We would appreciate any help that you can give us to reduce this trouble.

Blistering of plated die castings is by no means uncommon and may be due to several causes. It is quite possible, however, that in your case the main trouble is due to overcleaning.

Even a good die casting is somewhat porous and if it is left too long in the cleaning solutions it is likely to soak up some of the solution into the pores of the metal which will later react with it to produce a small blister of the type you describe.

Blistering of this nature is often erroneously ascribed to insufficient cleaning and it quite often happens that when such blisters appear, the time in the cleaning bath is increased rather than reduced.

In dealing with a zinc-base die casting, the minimum of polishing necessary to produce an acceptable finish should be done. After polishing the casting should be cleaned in first liquid and then vapour trichlorethylene allowing the casting to cool

between the two operations. It should then be given a soak clean in a mild alkaline cleaner containing some 2 oz. each of sodium tri-phosphate and sodium metasilicate used just below boiling point, for a maximum period of 2 min. It should then be rinsed and immersed for some 5 seconds in 5 per cent hydrochloric acid, after which it should again be rinsed and plated in a Rochelle-type copper bath. The free cyanide of this copper bath should be kept between 0.5 and 0.75 oz. per gal. and the temperature should be about 35°C. The copper deposit should be at least 0.0003 in. thick. After this, the casting may be nickel plated.

Fabrication of Galvanized Holloware

1157. We have seen numerous references to the fact that many manufacturers of galvanized holloware in America and on the Continent fabricate from galvanized sheets instead of galvanizing after manufacture. It is claimed for this method that production costs are lower and speed of production is much higher. Can you inform us whether these claims are justified and if so, why this method is not more widely adopted in this country?

While it is true that until recently a certain amount of holloware in the U.S.A. was fabricated from galvanized sheet, at the present time the trend is towards galvanizing after fabrication.

One of the difficulties in the fabrication of such articles as buckets from galvanized sheet is the production of liquid-tight seams. There is also the problem of dealing with bare areas at sheared edges or spot welds, which require local treatment.

Under British conditions, for a given sheet thickness, the production cost of a bucket, for example, fabricated from galvanized sheet is only very slightly less than that of one galvanized after manufacture, while its service life might be expected to be much inferior.

Bright Finish for Lead.

1159. We would like to apply some sort of dipped finish to small castings in 90:10 lead-tin alloy to retain the bright lustre. A clear paint or lacquer will not do. Can you advise a suitable process?

We are not familiar with any chemical method of retaining the initial brightness of a lead casting but if any reader can supply the information we will be pleased to convey it to the enquirer.

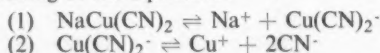
A Students Guide to Examination Courses in Metal Finishing

(continued from page 218)

action of the anode. In this case, however, the opposite state of affairs exists in that the solution around the anode will contain a higher concentration of copper sulphate than the bulk of the solution, and it will be necessary to arrange for this to be removed by diffusion, convection, etc. If, for some reason, the sulphate ions cannot reach the anode surface, then the potential of the anode will increase and may increase sufficiently to prevent any current passing through the system.

Alternately, if instead of using a copper anode, a lead anode is used which will not be attacked by the sulphate, then the sulphate ions on giving up their electrons to the anode will link with the water in the solution forming sulphuric acid and liberating oxygen. Under such circumstances it will be found that the voltage across the cell will rise considerable (from less than 1 to probably somewhere around 4). The surface of the lead will be found to have a layer of lead peroxide formed on it and a steady stream of molecular oxygen will be evolved. The solution itself will gradually become weaker in copper and if the electrolysis is continued all the copper can ultimately be deposited from it, leaving a solution of sulphuric acid. If the electrolysis is continued, hydrogen only will be liberated at the cathode and oxygen at the anode.

The above example of the electrolysis of a copper-sulphate solution has been taken as a typical elementary example. The same general facts apply to any system, but they may vary quite considerably with the metal and the type of salt. For example, if instead of using cupric sulphate, copper (cuprous) cyanide is used, a somewhat different state of affairs will exist. In the first place the copper will be in the cuprous condition and the ion will have only lost one electron instead of two. In point of fact cuprous cyanide is insoluble in water and the solution which must be used in the cell is a double cyanide of either potassium or sodium cyanide, and copper cyanide. In the first place these only give a sodium or potassium ion and therefore it might appear difficult to explain how copper is obtained. In the past there has been some controversy on this matter, but it is now usually agreed that a secondary ionization takes place according to the equations:



This produces a very small quantity of cuprous ions. When the solution is electrolyzed, these cuprous ions are deposited in preference to the

sodium or potassium ion. Since there is a fair amount of un-ionized copper in the solution adjacent to the electrode, as soon as these ions are deposited a further quantity is produced and so the supply is kept up. In this case a given quantity of current will deposit just twice as much copper as it would do from the sulphate solution, because the copper only requires to gain one electron instead of two at the electrode before it can become atomic copper. However, more energy is required because a higher voltage is necessary in order to pass current through the cell. Conditions under which the copper is deposited are somewhat different because due to the low concentration of copper ions present in the cathode layer, a higher cathode potential is required to maintain the flow of current and this generally produces a finer crystal structure.

At the anode the cyanogen ion is liberated and attacks the copper reforming copper cyanide, which dissolves in the excess of sodium cyanide present. The solution is somewhat alkaline so that the concentration of hydrogen ions in this case is extremely small. However, a certain amount of hydrogen may be liberated at the cathode and often is. This, however, may be due to the deposition of a certain amount of alkali metal which attacks the water and liberates hydrogen by a purely chemical action.

(Series to be continued)

B.I.F. (continued from page 214)

Effective use of modern resistant materials in the construction of plating shops and plating plant was revealed by a study of the exhibits staged by **Prodorite Ltd.**, which included acid-resisting cements and floorings and a range of tanks fabricated from, or lined with plastic.

In the foregoing brief survey of exhibits of metal finishing interest on show at Castle Bromwich, there have inevitably been many omissions, and it has only been possible to give some indication of the type and range of the exhibits in this field and to mention some of the new developments in evidence there. There are, of course, a large number of firms of eminence in the metal-finishing industry who do not choose to exhibit at the B.I.F., although they are just as active in the production of new developments as those who do exhibit. Similarly it is not to be expected that at an Exhibition staged at twelve-monthly intervals every exhibitor will be able to feature something novel. Nevertheless a visit to the Castle Bromwich section of the Fair is not unrevealing concerning the state of the metal-finishing industry in this country, and also, judging by the comments from many of the exhibitors, the leasing of a stand can result in a useful amount of business.

FINISHING

NEWS REVIEW

**CONTRACT-PLATING FIRM ANNOUNCES
NEW EXCLUSIVE-PLANT SCHEME****Chairman Reports Record Trading Year**

In a statement to the shareholders at the annual general meeting of William Bate (Holdings) Ltd., electroplaters of Walsall, Staffs., the Chairman, Mr. Geoffrey Bate, reported that the available profits, after meeting all administrative costs and taxation, for 1954 constituted a record for the company, and he attributed this not only to the sustained volume of business, but also to increased efficiency obtained by improved methods, higher technical standards and better equipment.

Mr. Bate also referred to a new scheme inaugurated by his company, which in effect is to provide plant at the company's premises for customers who have a sufficient volume of business. This plant is built, equipped and operated by the company, but is exclusively devoted to the customer's work and the customer has access to all matters concerning it much as if it were his own.

Of the two plants coming into operation under this scheme in the near future the first is being allocated to a firm of cooker manufacturers who, for the purpose of being in command of all their production processes would have liked to do their own plating, but decided that it would be very much easier to buy someone else's experiences rather than plunge into a large capital outlay in a business about which they know nothing (and in which even the experts find quite a few headaches). For this work a new building has been erected of approximately 4,000 sq. ft. comprising polishing shop, plating shop, warehouse, inspection, racking and wiring shop, control office, simple test laboratory and maintenance shop.

The components produced by the client being rather varied, automatic handling is not economical in this instance, so orthodox polishing and chromium plating is the general principle of production. The client's inspection and progress staff have complete access to the premises although the plant is actually operated by production and administration staff of William Bate Ltd. who have undertaken to cope with all the client's finishing requirements on whatever scale production should warrant. For example should a new cooker design require more plating this will not involve the client in extra capital expense or additional practical problems. The service will be automatically provided whatever the scale of requirements and if automatic handling

is warranted this also will be provided to the economical advantage of both companies.

In planning any future designs the experience of the William Bate Organization will be available for guidance in manufacturing in the most economical manner to reduce finishing costs.

William Bate Ltd. claim that the cost to the customer is quite definitely no more than he would pay in competitive outplating and a discount at the end of each year will have the effect of reducing what would be his normal plating costs.

The second plant is being provided for a firm who make very large quantities of zinc-base die castings which require chromium plating. This again is a new building of about 5,000 sq. ft. and is being equipped with fully automatic polishing and fully automatic plating facilities to suit the requirements of their particular work. The amenities are much the same as in the first plant with the exception that provision is being made for an extension to allow the customer to carry out a small assembly and if necessary to pack and despatch, giving him the advantage of a useful extension to his own works and saving a considerable amount of handling and transport.

This plant is not yet fully in production, but it is expected to show very considerable advantages to the client.

Another example of the kind of individual service provided by the company is the plating of large quantities of hub discs for a motor

manufacturer. This work started five years ago and while there has never been any arrangement similar to those described above, a fully automatic polishing and plating plant has eventually been installed to cope with approximately 20,000 discs per week and this plant is totally given over to this particular job.

The Company believe that this principle of exclusive plant provides a useful opportunity for the manufacturer who would like to do his own plating but does not wish to lock up the necessary capital, or alternatively for the manufacturer who has discovered by experience that the savings it is possible to achieve by doing his own plating are very often illusory.

In fact if many internal plating shops operated by manufacturers were properly costed on a realistic basis it would be found that the manufacturer who pays a fixed price to a specialist organization is really in the long run getting a cheaper service.

**New Vice-President for
International Nickel**

The International Nickel Company of Canada Ltd., have announced that Ralph D. Parker, of Copper Cliff, Ontario, has been elected vice-president, and Walter A. McCadden, comptroller of the Company.

Mr. Parker, who continues in his existing post of general manager of Canadian operations is president of Canadian Nickel Company Ltd., exploration and prospecting subsidiary of I.N.C.O.

Mr. McCadden, the newly-elected comptroller, has been assistant comptroller of the company since August, 1949. He succeeds as comptroller Cameron R. Whitehorse, who, having reached retirement age, has elected to retire under the company's retirement system. Mr. McCadden joined International Nickel in October, 1935, as a tax accountant. He was named assistant to the comptroller in January, 1948, and assistant comptroller in 1949. Prior to his association with International Nickel, he had been senior accountant with Price, Waterhouse and Co., New York.



Hungary Trebles Chemical Output in Five Years

HUNGARY's chemical industry has achieved a threefold overall production increase in the past five years. Mr. Árpád Kiss, Minister of Chemical Industries and Power wrote in an article in the newspaper Szabad Nép summing up progress in the last ten years.

Here are details of increases in various sections of the industries.

In the past five years:—

Caustic soda: Twofold increase

Sulphuric acid: Twofold

Oil paint and lacquer: Two and a half times

RIGID PVC IN THE ELECTROPLATING INDUSTRY

Because of its outstanding resistance to acid corrosion and the ease with which it is fabricated, rigid Geon PVC was used by Plastic Constructions Ltd. in making these exhaust ducts and hoods for acid-fume extraction during plating operations.

Rigid Geon PVC is readily shaped after being softened by heat, and sheets of this material are quite easily built up into large installations by means of hot gas welding, as is clearly shown in the illustration.



Zinc-Rich Paints Combat Metal Corrosion

THERE is a considerable demand for efficient paints of an anti-corrosive nature, particularly where iron and steelwork is concerned. For many years, such paints have been produced by the blending of zinc dust pigment in the paint compound. Durham Chemicals Ltd., manufacturers of paint materials, have been carrying out an intensive laboratory investigation concerning the problems of incorporating this pigment in the paint and have just published a report which should interest paint manufacturers and users alike.

It has been known for some time that a metal-to-metal contact between the particles in the paint film is essential for an effective galvanic protection but this calls for a high proportion of zinc dust pigment, as high as 92/95 per cent in the dried paint film. Paints manufactured accordingly are termed 'Zinc-Rich Paints' and the problems inherent in the demand for such a high pigment/binder ratio (19 : 1) are considerable. It is impossible to load a linseed-oil binder with such a quantity of zinc dust, and the modified alkyd resins find difficulty in maintaining a brushable consistency with 90 per cent zinc content. Chlorinated rubber and polystyrene binders prove practicable, however, though most formulae require the addition of a small amount of plasticizer to ensure the right degree of elasticity in the film.

Durham Chemicals Ltd. have, during their investigations, evolved a number of successful paint formulations which contain a minimum 95 per cent zinc content in the dry film.

Storage difficulties have been obviated by the marketing of the paints on a two-pack basis for mixing just prior to use. Small quantities of the paint, for household application, can now be bought in small, easily-stirred containers and, for larger quantities, these paints may be obtained in paste form not subject to serious settlement and which can be thinned to the right consistency before application.

'Zinc-Rich Paints,' though usually applied by brush, are suitable for dipping and spraying. Although it has been claimed that these paints can be successfully applied over a badly-rusted surface after only a rough brush-down, it has been proved that a thorough cleaning produces more effective results. When these paints are thinned for spray application it is essential that no portion of the coat is denuded of binder as this will lead to poor adhesion and short service life.

Durham Chemicals Ltd. supply paint ingredients and formulation knowledge to leading paint manufacturers, who in their turn make and market the paints which may be obtained through normal paint stores and suppliers.

WATER POLLUTION RESEARCH REPORT

Biological Destruction of Cyanides in Plating Wastes

THE annual report of the Water Pollution Research Board and of the Director of Research, published last month, includes an account of the new laboratory in Stevenage, which was occupied during the year. Progress made in the survey of the Thames estuary and in investigations on the effect of pollution on fish is described, and also work on the treatment of water, sewage, and industrial effluent.

An item of interest to the metal-finishing industry contained in the report of the previous year was the fact that some cyanides could be destroyed by biological action in a percolating filter. The organism responsible for this effect has now been isolated and classified as an Actinomycete.

As biological destruction might well prove to be useful for removing cyanides from industrial waste waters, further experiments were made to find whether the process would work

under conditions simulating, as nearly as possible, those which might be found in practice. To a filter was applied a solution in tap water of potassium cyanide and the complexes of the metals commonly plated from cyanide solutions, that is zinc, cadmium, and copper; the concentration of each cyanide was equivalent to 25 p.p.m. HCN, giving a total concentration of 100 p.p.m. HCN.

The results showed that the mixed cyanides were treated quite satisfactorily, the average concentration of cyanide in the final effluent being rather less than would have been expected if 100 per cent of the cyanides of potassium, zinc, and cadmium, and 80 per cent of the cupro-cyanide had been destroyed. About 50 per cent of the nitrogen of the cyanide appeared in the effluent as ammonia, nitrite, and nitrate.

A commercial firm is reported as giving the process a trial in a pilot plant for treating quenching waters from the cyanide hardening of steel.

The report is published for D.S.I.R. by Her Majesty's Stationery Office at 3s. 0d.

CORROSION BY FERTILIZERS

Agricultural Problems Discussed at London Meeting

A ONE-DAY Conference on a very specialized but no less important aspect of corrosion was held in London at the Royal Society of Arts on April 21. Dealing with the subject of the corrosion of metals by agricultural fertilizers it was organized jointly by the Institution of British Agricultural Engineers and The Fertilizer Society. Four papers were given, dealing with the mechanism of corrosion, methods adopted by fertilizer manufacturers to reduce attack, corrosion of steel in relation to fertilizer chemicals, and problems of its prevention on the farm.

Mr. W. D. Clark, of Imperial Chemical Industries, explained the chemistry and metallurgy of the problem of corrosion. After explaining simply the various modes of attack, and protective measures which could be taken, he gave data specific to fertilizers. Some of his points may be summarized as follows:—The corrosive powers of a substance depend chiefly on the factors—acidity, oxidizing power, and ability to penetrate surface films. Specific factors arise with certain combinations such as ammonia and copper alloys and high alkalinity and aluminium and zinc. Most important, in the absence of moisture, corrosion will, in general, be negligible.

Design of Equipment

The corrosion of steel in relation to fertilizer chemicals was discussed by Mr. C. R. Pipe of Richard Thomas & Baldwins, Ltd. His paper gave some suggestions as to equipment design to minimize corrosion. The design of equipment to handle fertilizer chemicals, he stated, is the province of the manufacturer of such equipment, but in relation to reducing corrosive attack, a few of the major principles are worthy of mention. The primary requirement is to ensure that lodgment of fertilizers at inaccessible zones is impossible. Machines should be so constructed that, after use, no chemical is retained in pockets and crevices where corrosion can proceed unchecked. Again, construction should

be such that joints are tight enough to allow of no deposition of moisture even by condensation. Lack of access of oxygen at such positions, even without the added effect of a fertilizer chemical, can lead to a rapid rate of corrosion due to differential aeration. In this respect, a welded construction is generally superior to riveting. Finally, machines should be provided with a generous supply of draining holes so that during washing out, or during heavy rain if the machine is out in the open, opportunity is given for as much of the water as possible to be run out of the machine.

Fertilizer Distributors

Fertilizer distribution was discussed by Mr. R. Paterson. He summarized his recommendations on cleaning of fertilizer distributors as follows:—(a) Wash off thoroughly immediately after final use and scrape clean. Do not wash off unnecessarily in damp weather during use, as a wet distributor may create difficulties. A dressing of diesel oil may be helpful during temporary storage. (b) Clean small parts in an acid bath. (c) Cover all metal immediately after use with a rust-preventing fluid that dries to a sticky, not a hard surface. (d) Maintain a good coat of paint on all surfaces. (e) Store with small moving parts left loose in the hopper.

The fourth paper, by Mr. J. E. Nicholson, of W. N. Nicholson & Sons, Limited, gave data on methods used by manufacturers to reduce the corrosiveness of fertilizers.



South African Laboratory opened by well-known British Chemical Engineer

Mr. J. A. Reavell at Official Ceremony

A new chemical engineering laboratory has recently been opened at Witwatersrand University, Johannesburg, to accommodate the increasing number of students taking the Chemical Engineering course and to provide facilities for teaching essential unit operations involved in chemical engineering.

The University has been greatly helped in this project by the generosity of a number of South African companies who have provided equipment. Prominent amongst these firms are Kestners (South Africa) (Pty.), Ltd., and W. S. Thomas and Taylor Ltd. Due to the rapid growth of the chemical plant industry in the Union in the post-war years it was possible for much of the new laboratory plant to be manufactured locally. For example, Kestners (S.A.) (Pty.), Ltd., have presented a stainless-steel climbing film evaporator and a stainless-steel spray drying plant complete with fans, air filter and heater all made in the Union.

The new laboratory has been called "The J. Arthur Reavell Laboratory for Chemical Engineering" and at the invitation of the University Council, Mr. Reavell travelled to Johannesburg to perform the official opening ceremony.

At the opening and reception there were about 100 guests by special invitation representing the Government of South Africa and many of the largest industrial companies in the Union.

In his address Mr. Reavell gave an interesting outline of the major developments in chemical engineering in the United Kingdom from the turn of the century up to the present day.

B.I.F. DATES CHANGED FOR 1956

THE British Industries Fair is to be held at two different times of the year from 1956 onwards. The first show will be at Earls Court, London, from February 22 to March 2. The second will be at Olympia, London, and Castle Bromwich, Birmingham, from April 23 to May 4.

Duke of Edinburgh to visit Aluminium Exhibition

H.R.H. THE DUKE OF EDINBURGH will visit the Aluminium Exhibition at the Royal Festival Hall during the morning of June 3. His Royal Highness will also lunch with the President and Council of the Aluminium Development Association and leading personalities connected with the industry aboard the *Wellington*.

The Exhibition, which opens on June 1 and closes on June 10, marks the centenary of aluminium as a commercial metal. It will tell the

story of an industry that has been built on research, the story being illustrated by a thousand exhibits, ranging from 'bus bodies, railway coaches and giant cranes, fashioned in aluminium, to window frames, roofing and many other applications of the metal in building construction. Also on show will be large vats used in brewing, cooking vats for the food industry, aluminium foil and its many uses, etc., etc.



CHANGE OF ADDRESS

The address of **Borax Consolidated Ltd.**, manufacturers of "20 Mule Team" brand boron products, is now Borax House, Carlisle Place, London, S.W.1. (Telephone: VICTORIA 9070.)

Aero Research Ltd., Northern Area Office has now moved to larger premises at No. 409, Royal Exchange, Manchester 2. (Telephone: Blackfriars 9445-6.)

The address of the **Zinc Development Association** and its affiliates **The Hot-Dip Galvanizers**, the **Zinc Alloy Die Casters**, and the **Zinc Pigment Development Associations** is now 34, Berkeley Square, London, W.1. (Telephone: GROSVENOR 6636.)

TECHNICAL AND INDUSTRIAL APPOINTMENTS

At the 54th Annual Meeting of stockholders of **Monsanto Chemical Company**, St. Louis, U.S.A., held on Thursday, April 14, 1955, Mr. Edward A. O'Neal, Jr., was elected to the board of directors of the Company.

At the board of directors' meeting following, Mr. O'Neal was appointed to the executive offices of the president as a functional vice-president. His duties will include the integration of overseas activities of Monsanto with activities of the rest of the company.

Mr. O'Neal will continue as chairman of **Monsanto Chemicals Ltd.**, which office he has held since 1949.

The following retiring directors were re-elected by shareholders at the annual meeting of **The International Nickel Company of Canada Ltd.**:

Edwin G. Baker, Chairman, The Canada Life Assurance Company; Lewis W. Douglas, Chairman, Southern Arizona Bank and Trust Company and The Mutual Life Insurance Company of New York; J. Roy Gordon, Vice-President of the company; H. R. MacMillan, C.B.E., Chairman, MacMillan and Bloedel Ltd.; The Rt. Hon. Viscount Margesson, P.C., M.C., Director of banking, electric, cement and other companies; R. Samuel McLaughlin, Chairman, General Motors of Canada, Ltd., and Vice-President, General Motors Corporation; H. C. F. Mockridge, Q.C., Member of the firm of Osler, Hosken and Harcourt; Theodore G. Montague,

TRADE and TECHNICAL PUBLICATIONS

"Tin and its Uses" No. 31. The Tin Research Institute announces in this issue of its quarterly journal that it is organizing an international exhibition. "Pewter of To-Day", in June this year, to take place in London. Exhibits are being lent by firms in most of the pewter-producing countries. After the London showing the collection will tour European and American cities.

Dr. Frederick Lowenheim explains in a four-page article how it is possible to step up the production from stannate tin-plating baths by substituting the sodium salts by potassium salts. He also describes a patented tin-alloy anode that aids in faster plating.

Chemical balance weights are now being plated with the new tin-nickel alloy electroplate; according to the article, the tin-nickel plating is preferable to gold plating for this application.

Two pages of news items indicate some of the current activities of the Institute and its branch offices in eight countries.

"Tin and its Uses" No. 31, is obtainable free on request to the Tin Research Institute, Fraser Road, Greenford, Middlesex.

"F.B.I. Review": The April issue of this publication from the Federation of British Industries, 21, Tothill Street, London, S.W.1, contains an article on "Sandwich Courses." This type of course, in which practical industrial training and full-time theoretical studies at a technical college alternate, have today a much greater contribution to make to industry than hitherto. The article, by Dr. P. F. R. Venables, principal of Salford Royal Technical College, is the second of a series which is being published in the Review; it discusses the conditions for establishing sandwich courses.

Control of Processes: A new illustrated booklet surveys the scope of the products and service in the control of processes of George Kent and Co. Ltd., Luton, Bedfordshire. The booklet covers such fields as water measurement, steam, air and gas measurement, oil, petrol and temperature measurement, pH and conductivity measurement, etc., etc., and also deals with automatic process control.

A new leaflet from the company describes and illustrates the KU flow meter, a new industrial instrument, for the measurement by differential pressure of the flow of water, steam, oil, gas or other fluids.

RAW MATERIALS

Lithium Salts

Fisons Ltd. have announced that they now represent the Foote Mineral Co. of Philadelphia for the sale of lithium salts in the U.K. and Europe including Scandinavia.

The Foote Mineral Co. have long been associated with the development of uses for lithium salts which are now being used increasingly in the manufacture of vitreous enamel frits.

Sales in the U.K. are being handled by Whiffen & Sons Ltd. and overseas by Fisons Chemicals (Export) Ltd. both of North West House, Marylebone Road, London, N.W.1, from whom samples, prices and details of availability may be obtained.

Bentonite

The Board of Trade has announced that bentonite, a clay used in vitreous enamelling and paint manufacture, can be imported from all countries without individual import licences from May 13, 1955. Imports from dollar sources have hitherto been subject to licensing control.

President, The Borden Company; R. L. Prain, O.B.E., Chairman of Rhodesian Selection Trust Ltd., of Mufulira Copper Mines Ltd. and of Roan Antelope Copper Mines Ltd.; George C. Sharp, Member of the firm of Sullivan and Cromwell; John F. Thompson, Chairman of the company; and The Rt. Hon. Viscount Weir, P.C., G.C.B., Chairman, G. and J. Weir Ltd.

Mr. A. Holroyd, A.M.I.Chem.E., has been appointed for a period of four years a member of the Water Pollution Research Board of the Department of Scientific and Industrial Research. He succeeds Mr. F. S. Jenkins who has completed his term of office. Mr. Holroyd was formerly sewage works manager, Wolverhampton.

Mr. J. Rutter has been appointed a technical representative of **The Jenzolizing Co. Ltd.**

Mr. Kenneth Horne, who in addition to being well known as a television and radio personality is also a prominent businessman, has been appointed full-time managing director of **British Industries Fair Ltd.**, the company formed last year to take over the Fair from the Board of Trade. Mr. Horne will give up his position as sales director of **Triplex Safety Glass Ltd.**, having been with the company for 27 years.

Latest Developments in

PLANT, PROCESSES and EQUIPMENT

Low-temperature Stoving Zinc-rich Primer

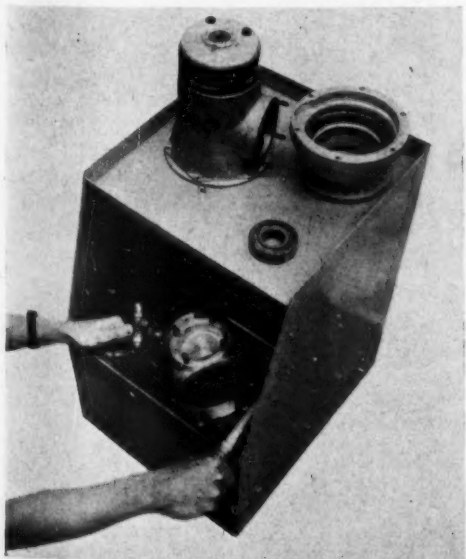
CORROSION Ltd., 16, Gloucester Place, Portman Square, London, W.1. announce the introduction of Glopane Stoving type LT, a new low-temperature stoving zinc-rich paint. This is in addition to the high-temperature stoving zinc-rich paint that they have made for some years.

This new type of paint is a true zinc-rich paint as defined by the British Iron and Steel Research Association, and gives sacrificial protection of the kind associated with metallic zinc coatings generally (e.g., hot-dip galvanizing) when applied to iron and steel. The practical expression of this is that rust cannot creep under the coating.

Glopane Stoving type LT has been formulated to fit in with stoving schedules for the normal types of stoving finish used by manufacturers of domestic equipment, vehicles, etc. Typical stoving schedules are: 15 minutes at 300°F., 30 minutes at 270°F.; 60 minutes at 212°F. By infra-red in suitable cases stoving time is between two and three minutes. The stoved coating has high adhesion, and is very hard, tough and durable.

The new paint results in a smooth, fine-grain finish which does not need rubbing down even when used on products (e.g., motor cars) on which the highest class of finish is necessary. It is applied by any normal technique. In particular, its sprayability

Fig. 1.—The "Paraminor" Multi-Purpose Washer.



is better than is the case with normal types of zinc-rich paint. The coverage of the material is high, and it is therefore economical in use. There is no sedimentation of the pigment in the can or spray-gun reservoir, and therefore no more than normal agitation is needed before use and none during use. The general can stability of the material is very high.

Multi-Purpose Washer

DESIGNED to meet the need for a small, compact and efficient washer is the new De Laval "Paraminor" (Fig. 1)—a development of the larger and well-known Parawash equipment—now made available by Alfa-Laval Company Ltd., Great West Road, Brentford, Middlesex.

The "Paraminor" is of strongly welded-steel construction and incorporates an efficient hand-operated pump of unique and simple design capable of delivering at a rate of over 300 gal./hr. at 20 lb. sq. in. A specially designed multi-head jet head can be adjusted for fine or coarse sprays or for a solid jet.

An effective easy-clean filter is fitted and filter-medium replacement costs are only a few shillings yearly. The sump has capacity for 2 gallons of cleaning fluid.

The complete unit which measures 15 in. wide, 19 in. deep and 23 in. high can be placed on any bench or tool locker without fixing and requires no electricity, gas or water.

The "Paraminor" is designed for paraffin, white spirit or a cold cleanser but it can also be used for oiling new parts before storage or assembly besides being adaptable for coating parts with rust preventive, etc.

Pocket Thickness Gauge

THE O. Hommel Co., Pittsburgh, Pa., U.S.A., announces that an accurate miniature thickness gauge is now available, which measures vitreous-enamel coatings.

The gauge (Fig. 2) which is a single probe type, enables thickness measurements on most curved as well as flat surfaces with greater ease than formerly possible. It will show the measurement of thickness of non-ferrous layers on cast, wrought, forged or sheet iron and steel bases of permeabilities between 200 and 8000. It can be used on iron or steel castings, strips, rod or tube, and flat or curved sheets.

The instrument is provided with a zero adjuster and locking nut which enable the zero to be set to suit the base when measuring the thickness of the coating. The adjuster is provided to allow for variations in size, thickness and permeability of the bases. A maintenance service is provided by the company. For complete details, contact the O. Hommel Co., P.O. Box 475, Pittsburgh 30, Pennsylvania.

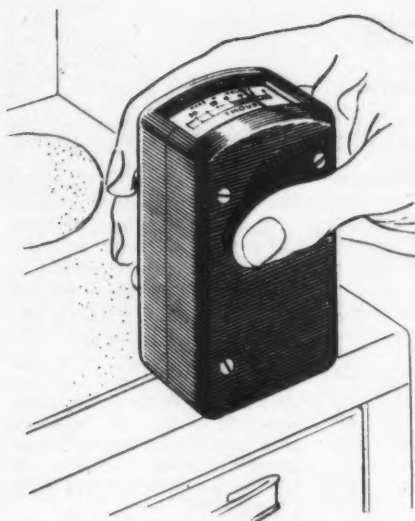


Fig. 2.—Pocket Thickness Gauge.

Paint Strainer

RECENTLY introduced by B.E.N. Patents Ltd., High Wycombe, Bucks., is the Freeflo paint strainer, a fine mesh brass screen which is fitted inside the containers of spray guns of the underslung container type. It is suitable for use with all types of syphon feed and internal mix pressure feed spray guns with material tubes of $\frac{3}{8}$ in. outside diameter.

The incorporation of this strainer provides that all paint is strained before reaching the spray nozzle, eliminating clogging and spitting even with heavily skinned paints, and helps to ensure a clean and smooth finish. Tests have indicated that the presence of the strainer has no effect on the speed of coverage, and cleaning is simply effected during routine cleaning of the spray gun.

Steel Swilling Basket

A NEW basket (Fig. 3) made from perforated steel, as distinct from the normal wire-mesh product, is being produced by Tool Treatments (Chemicals) Ltd., West Bromwich. The design of the basket is such that very efficient swilling and draining is possible, and the manufacturers claim that its life is longer than conventional wire-mesh types. The depth of the "Black Knight" basket is 10 in. with a 10-in. high handle. The diameter is $7\frac{3}{8}$ in. and the general construction is in $\frac{1}{16}$ -in. perforated steel with holes of $\frac{3}{16}$ in. diameter. The top and bottom bands are in $\frac{1}{8}$ -in. thick strip, $\frac{1}{2}$ in. wide.

Spraying of Anti-corrosive Compound

THE Regent Oil Co., Ltd. and the Atlas Diesel Co., Ltd. have recently co-operated in developing a hot spray method for applying semi-solid anti-corrosive compounds. The difficulties of effectively spraying such compounds are well-known and more often than not excessive quantities of thinners are required.

Fig. 3 (right)—Steel swilling basket.

The newly developed "hot spray process" is the result of experiments with the Regent Oil Co.'s Caltex Rustproof Compound L and the Atlas Diesel Co.'s KV3 Cup Heater and Ecco 306 Spray Gun.

The compound, which contains 12 per cent volatile thinner, is heated in the cup heater (Fig. 4) to 140 to 160°F. When the thinner has evaporated after application the melting point is 145°F. It is sprayed at a pressure of 45 lb. per sq. in. by the special internal

Fig. 4 (below)—Hot spray process.



mix Ecco 306 gun (Fig. 4) which gives the required atomization. When the globules strike the surface being sprayed, they congeal immediately thus eliminating wasteful backspray, resulting in an even coating that covers effectively.

Compound L, a semi-solid, is a blend of mineral oils and petroleum jelly containing special additives, which give it non-drying, flexible and high adhesive qualities, thus providing a protective coating or film that does not harden or crack, that will withstand rough treatment and tropical or arctic temperatures. None of these qualities are lost by use of the hot spray method.

An advantage of Compound L is that it can be sprayed on a surface that is not completely free of moisture. The film or coating absorbs any moisture and then expels it to the "weather" side where it is lost through evaporation.

